Institute of Hydrology

Natural Environment Research Council

Bursa Environment Project

Report on

Hydrology and Water Quality Modelling

Institute of Hydrology
Wallingford
Oxon
OX10 8BB

December 1991

BURSA ENVIRONMENT PROJECT

REPORT on

HYDROLOGY AND WATER QUALITY MODELLING

Table of contents

BURSA ENVIRONMENT PROJECT

REPORT on

HYDROLOGY AND WATER QUALITY MODELLING

List of Tables

BURSA ENVIRONMENT PROJECT

REPORT on

HYDROLOGY AND WATER QUALITY MODELLING

List of Figures

1 INTRODUCTION

1.1 Context of Hydrological Study

At present the Nilufer River acts as the main route by which liquid waste is transferred out of Bursa and the surrounding area. Outfalls of untreated effluent from both domestic and industrial areas discharge directly into the river; in addition smaller outfalls discharge into many of the small torrents which flow from the Uludag mountain through the urban area before they join the main river. Some of these water courses dry up in the summer, as water infiltrates into the underlying alluvium. Any pollutants that then remain on the surface are washed further downstream at the onset of periods of sustained flow.

Any study of the sewerage system of Bursa must therefore include a review of the hydrology of the Nilufer, and its capacity to assimilate waste.

This report on hydrology and water quality modelling begins by giving a general background to the study area. The sources of hydrological and meteorological data are reviewed, and the flow regime of the Nilufer is analysed. The existing water use of the river is summarised, and is followed by an overview of the existing water quality data. A description of the water quality model is then given, and is used to demonstrate the effect on downstream river water quality of alternative proposals for sewage treatment works. Some comments for additional data collection and water quality modelling are then given.

1.2 Study Area

The catchment of the Nilufer River drains the northern and western slopes of the Uludag mountain. The main river flows out of the mountains to the west of Bursa, before turning eastwards along the foot of the steep mountain slopes (Figure 1.1.1); the river then turns back on itself, before flowing into the Simavi River some 50 km to the west of Bursa. Just north of Bursa, near the point where the main road to the north crosses the river, the Nilufer is joined by a network of irrigation drainage canals that collect water from the eastern part of the basin.

There are many small creeks and torrents which feed the Nilufer along its course through the urban area. Some of these are fed by springs that have been used for water supply over many years; other watercourses flow intermittently after rainfall, or in the spring when they are fed by snowmelt from the mountains.

Downstream of Bursa, the river meanders through a flat alluvial plain to the east and the north of the city, where there is extensive agricultural development. Some of the area is supplied with irrigation water from groundwater.

1.3 Climate

Bursa is located in the Marmara region, a transitional zone between the more continental climate of the Black Sea, and the Mediterranean Climate. The climate is hot and arid in summer, and rainy to lukewarm in winter; during the winter snow is common on high ground.

The pattern of rainfall is illustrated by the mean monthly rainfalls shown in Table 1.3.1. At Bursa almost 70 percent of the annual rainfall falls in the wet season from December to June; at higher altitudes the percentage of winter rainfall approaches 80 percent of the annual total. The table also shows the difference in the range of temperatures at Bursa and higher up the mountain. The local climate can change markedly over short distances, as a result of the steep gradients on the northern slope of Uludag.

Figure 1.3.1 shows the monthly distribution of rainfall and potential evaporation; in the winter months, rainfall exceeds evaporation, whereas in the summer months evaporation greatly exceeds rainfall.

1.4 Geology

The geology of much of the study area is described in detail in the DSI report on the hydrogeology of Bursa and Cayirkoy (Bursa ve Cayirkoy Ovalari Hydrogeologik Etut Raporu, 1990); Figure 1.4.1 and 1.4.2 are simplified versions of the maps reproduced in the DSI report.

The Palaeozoic limestone formations provide spring discharges into the valley. The springs on the north-facing foothills of Uludag have provided a reliable water supply for Bursa over many years. In the area of Bursa Cekirge there are thermal springs recharged by deep faults.

The main features of the Nilufer valley are well illustrated by the cross-section shown in Figure 1.4.2; once the river debouches onto the plain, it flows over alluvial deposits that overlay Neogene formations. The thickness of the alluvium is between 80m and 200m, and the Neogene formations between 500m and 600m. The alluvium has high transmissivity in comparison with the Neogene deposits. At some points in the valley the alluvial aquifer is recharged by the river; at other points artesian conditions exist and groundwater flows back into the river. There is extensive groundwater pumping for irrigation.

The tertiary sandstones form the hills between the Bursa valley and the Sea of Marmara. The sandstones confine the Nilufer to a narrow gap where it flows westwards at Gecit. Downstream of Gecit the left bank tributary, Avvali D., flows into the Nilufer. This catchment is separated from the Nilufer by an outcrop of the Neogene.

Location map

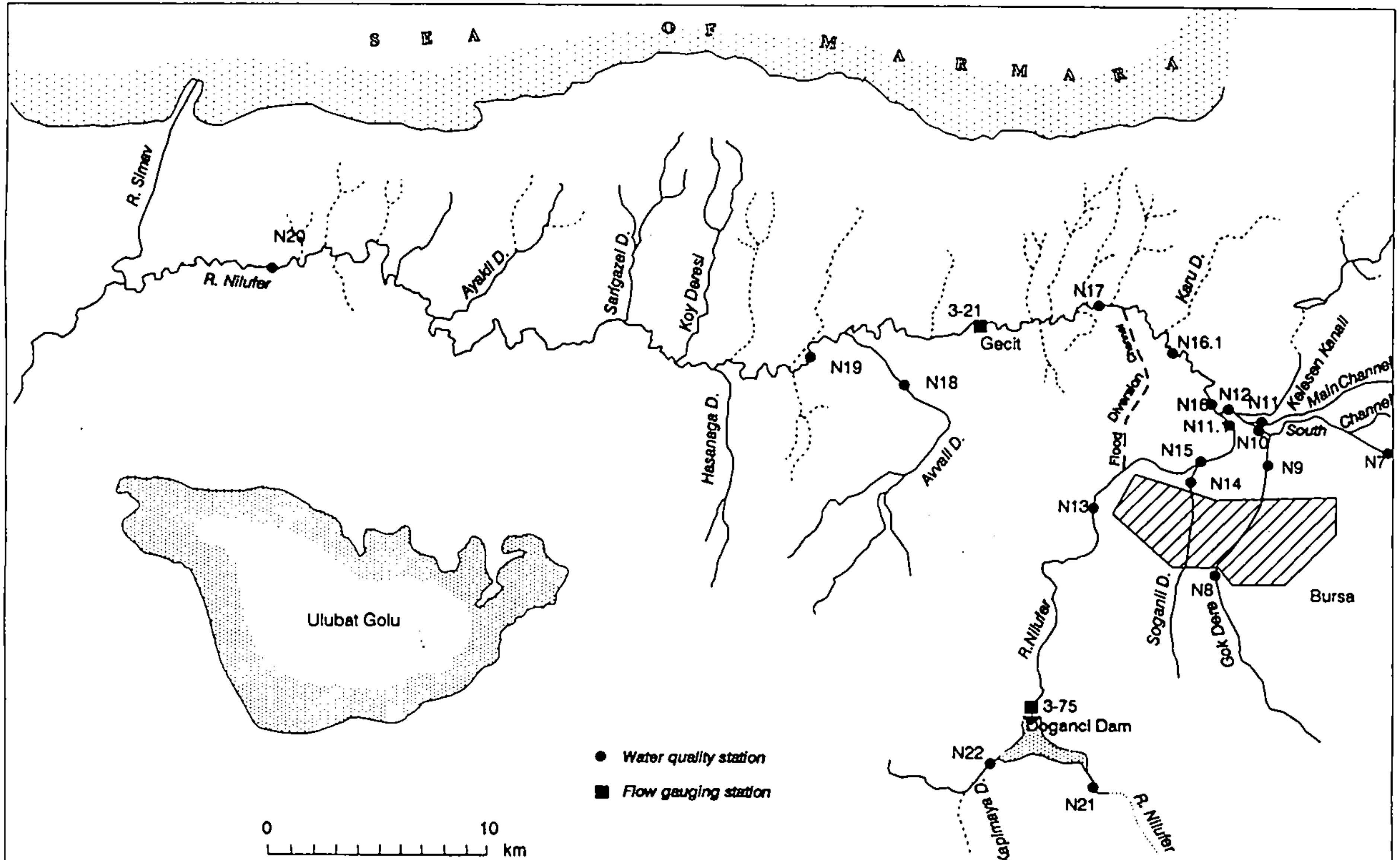


Figure 1.1.1

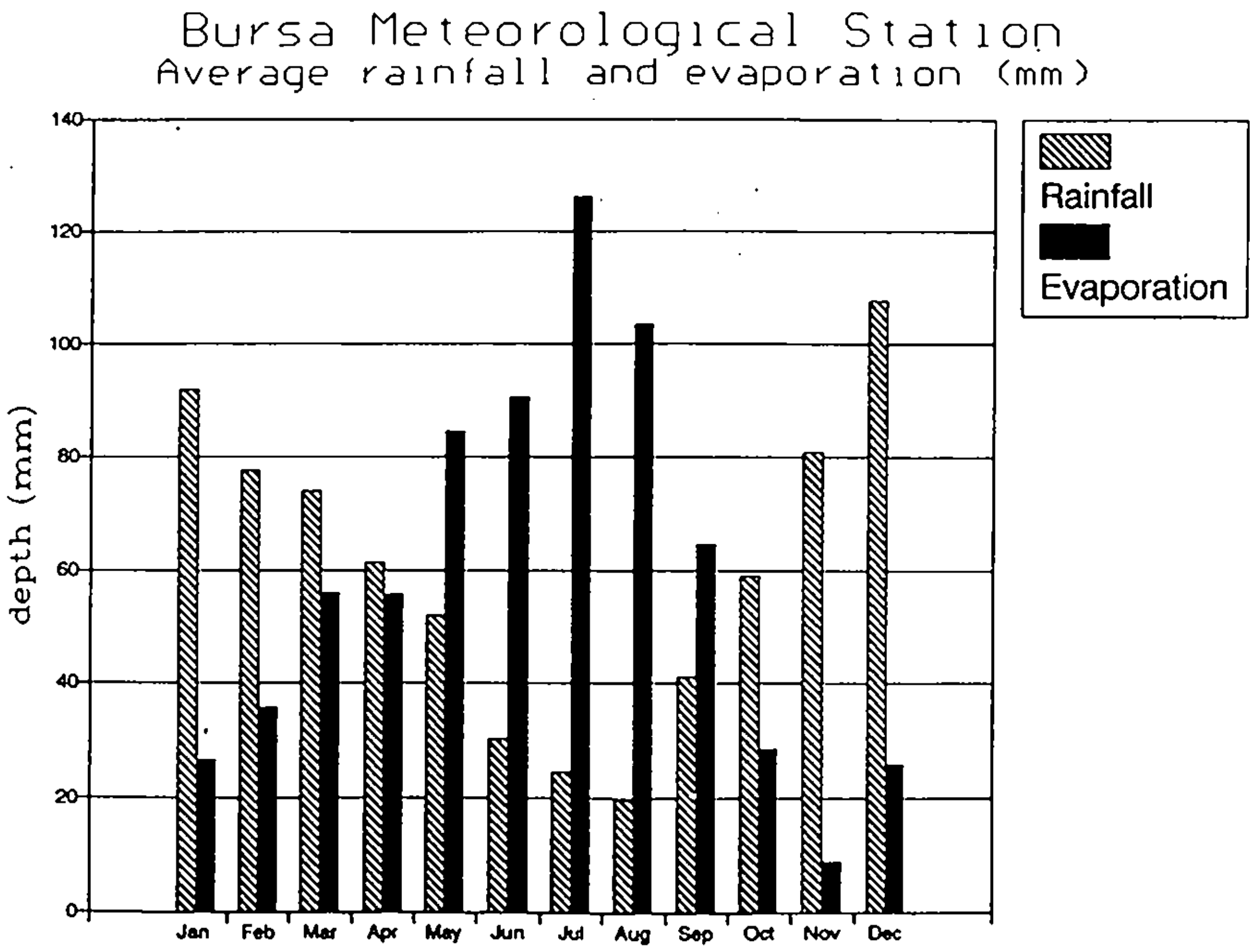

Bursa Meteorological Station
Average rainfall and evaporation (mm)
depth (mm)
0
20
40
60
80
100
120
140
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Rainfall
Evaporation

Figure 1.3.1

Table 1.3.1 Climate data in the project area

Bursa Meterological station (alt. 100m)															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Wet season	Dry season
Mean temp (°C)	5.2	6.0	8.0	12.6	17.4	21.6	24.2	23.9	19.7	15.4	11.3	7.5	14.4	11.2	18.9
Mean monthly rainfall (mm)*	92	78	74	61	52	30	25	20	41	59	81	108	720	495	225
% annual total	13	11	10	9	7	4	3	3	6	8	11	15		69	31
Maximum daily rainfall (mm)	57.6	55.9	39.8	38.7	49.2	42.2	200.9	68.9	103.2	71.5	78.1	89.2			
Meand wind speed m^3S^{-1}	3.3	3.4	2.9	2.4	2.0	2.3	2.9	2.8	2.4	2.0	2.3	3.2	2.7		
Potential evaporation (mm)	27	36	56	56	85	91	126	104	65	29	9	26	707		
Uludag F A Zirve (1920 m.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Wet season	Dry season
Mean temp (°C)	-3.5	-4.4	-2.6	2.0	7.0	10.9	13.3	14.2	10.9	5.8	2.9	-2.9	4.5	0.9	9.4
Mean monthly rainfall (mm)	225	219	164	123	116	88	53	15	56	82	136	269	1545	1203	342
% Annual total	15	14	11	8	8	6	3	1	4	5	9	17		78	22

Sources of data:

i)	Temperature, rainfall and windspeed	Meteoroloji Bulteni, Basbakanlik Basimevi, Ankara, 1974
ii)	Potential evaporation	Bursa ve Cayiritoy Ovalari Hidrogeologik Eutu Raporu
*	Bursa rainfall	Bursa-Demirtas Baraji Planlama Raporu, DSI, ?

Note: Wet season defined as December to June
Dry season defined as July to November

Bursa plain: simplified geology

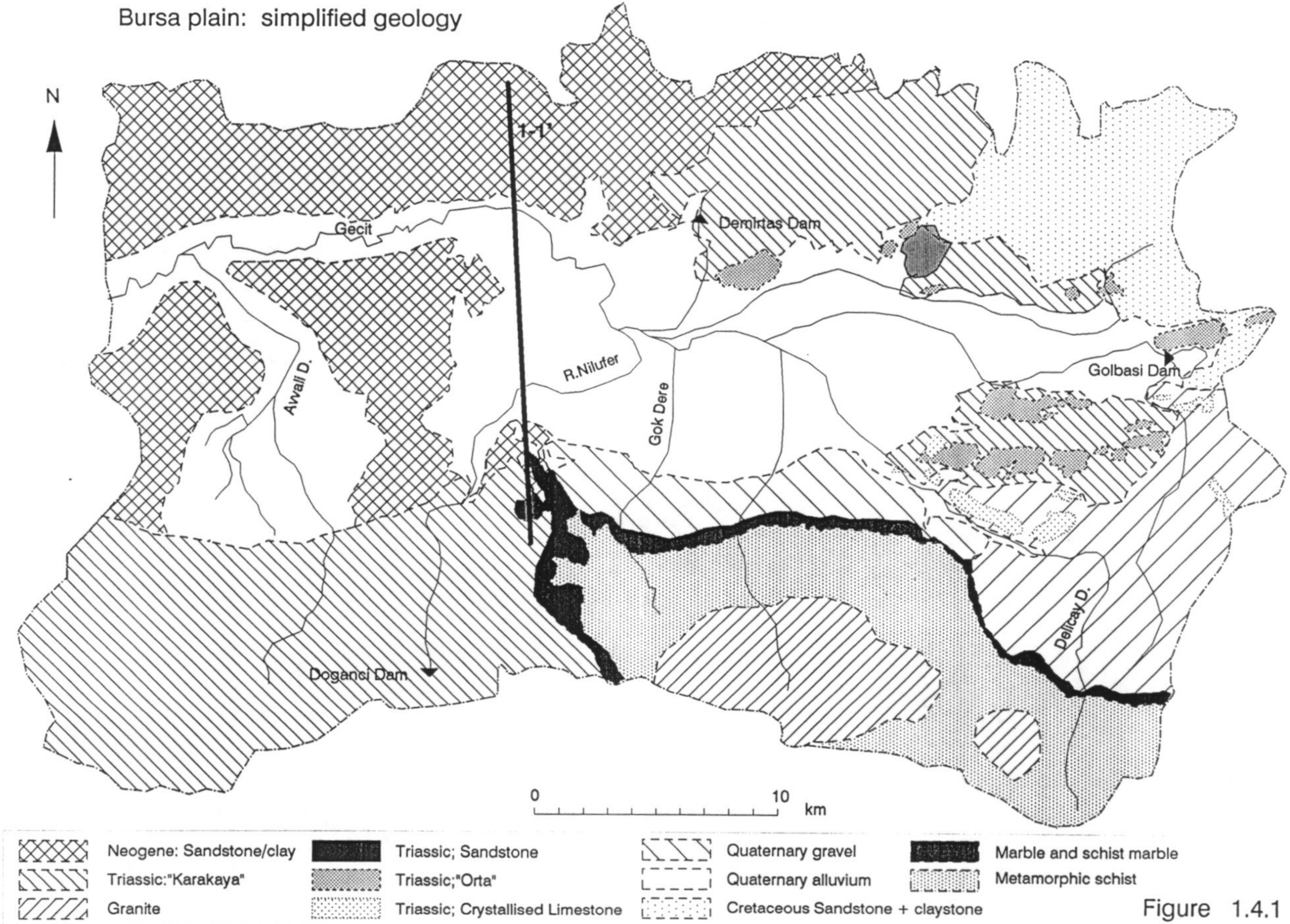
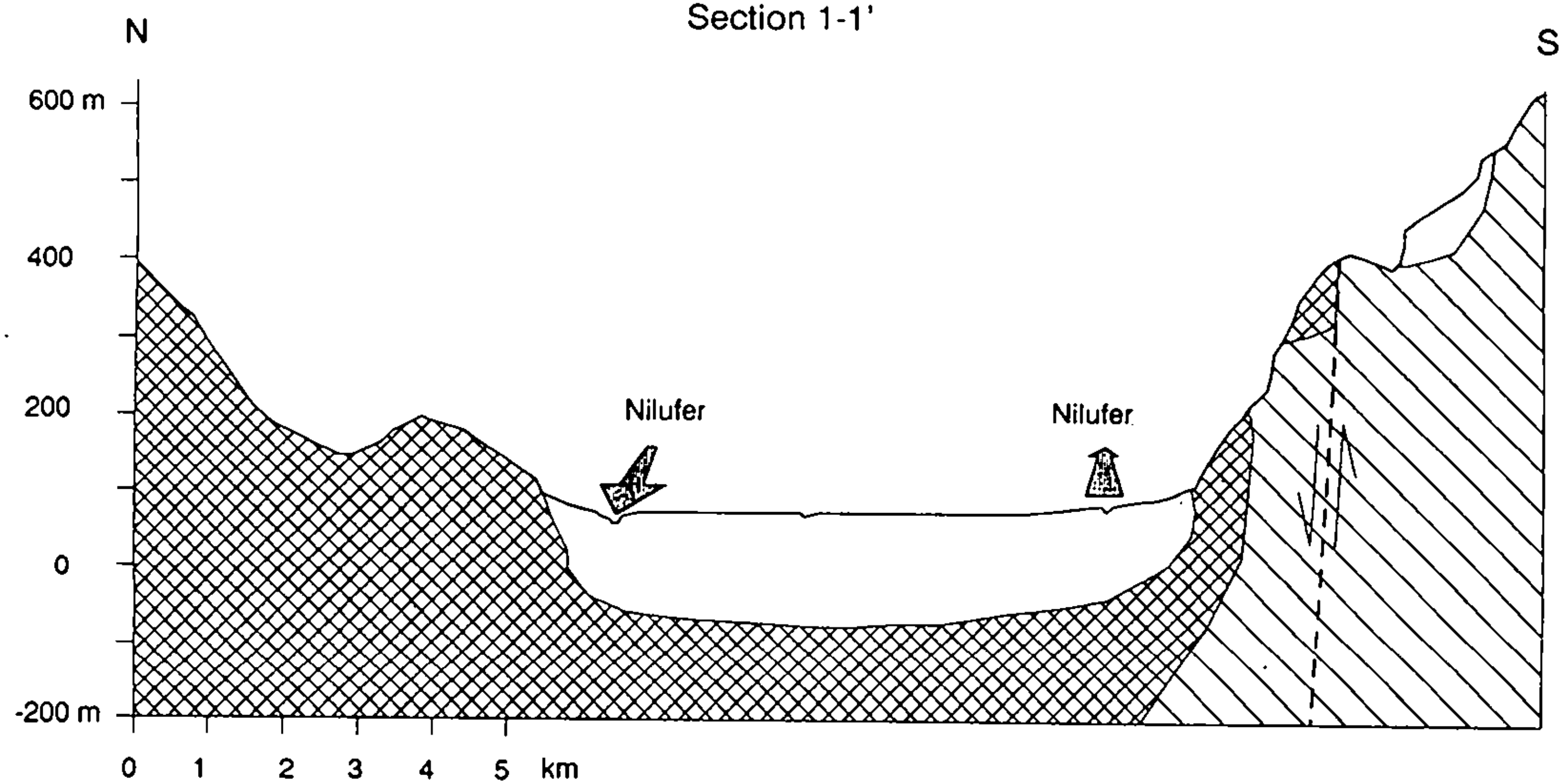


Figure 1.4.1

Bursa plain: Geological cross-section

Section 1-1'



For location of cross-section see Figure 1.4.1

Figure 1.4.2

2 HYDROLOGICAL DATA

The scope of the hydrological data collection exercise was restricted to data held at the Bursa office of DSI, and other data available from published yearbooks. Although some data are held on computer, it was not possible in the time available to arrange for the transfer of data on diskette. Consequently records were photocopied from manuscript records or yearbooks, and then entered by hand onto the project database. The hydrological data were processed using HYDATA, a PC-based hydrological data processing and analysis package; the water quality data were processed on a standard spreadsheet program. The time available for the study did not permit any quality control of the data, which were accepted in their published form.

2.1 Rainfall

Raingauges in and around Bursa are operated by the Meteorological Department and by DSI. Meteorological data were obtained from published reports and from relevant files and hydrological project reports.

The synoptic weather station in Bursa is located near the airport, and has records that extend back to 1929. Other rain and snow gauges higher up the Uludag mountains were installed in the 1930's. The distribution of mean monthly rainfall at Bursa is given in Table 2.1.1 and is shown in Figure 1.3.1; also shown is the mean potential evaporation. The plot shows an excess of rainfall over evaporation in the winter months from October through to April, with large deficits in the summer months.

Various DSI reports on hydrological studies in the region present a simple relationship between mean annual rainfall and altitude; typically mean annual rainfall increases by over 40 mm for each 100 m increment in altitude.

The distribution of annual rainfall at Bursa over the course of the record is shown in Figure 2.1.1; this is plotted as a cumulative departure from the mean in Figure 2.1.2.

The graph shows several consecutive years with rainfall greater than average in the early 1940's, followed by a drier period in the late 1950's. The plot suggests that rainfall has been lower than average in recent years.

2.2. Streamflow

Streamflow gauges in Turkey are operated by the EIE (Elektrik Isleri Etut) and DSI. In the study area, the main DSI gauges are located in the upper parts of the catchments. Data from these gauges are used mainly for the planning, design and operation of surface storage reservoirs. The locations of the main gauges downstream of the Doganci Dam are shown in Figure 2.2.1. Details of the gauges and the period for which records are available are shown in Table 2.2.1.

The DSI gauges provide data for only a small part of the overall study area; the EIE gauge at Gecit has a catchment area of 1290 km^2, out of the total catchment to the tributary with the Simavi of over 1900 km^2. It appears that there are no streamflow gauges downstream of Gecit, either on the Nilufer itself, or on its tributaries. Maintaining good gauges on the downstream reaches of the Nilufer is difficult for several reasons. Firstly the bed is very muddy and unstable, so it is difficult to obtain accurate cross-sectional measurements for the derivation of rating curves. Secondly the river water is considered to be highly polluted, and there are dangers associated with current metering. The EIE gauge at Gecit was the main source of streamflow data for the study.

2.3 Water Quality

DSI initiated a programme of water quality monitoring at locations in and around Bursa in 1984. The sampling points fall into two categories; points upstream of the Doganci Dam which are used to monitor water flowing into the reservoir, and points downstream of the dam, located throughout the urban and agricultural area. The locations of the main water quality sampling points are shown in Figure 2.3.1.

At first the sampling frequency was about six times a year, but this has fallen in recent years. A range of chemical and biological determinands are measured; flows are measured at the same time as the samples are taken. Photocopies of the records held by DSI were made, and the data entered by hand onto spreadsheets. Summaries of the statistics of the main determinands are given later in this report in Table 3.2.1.

The Table clearly demonstrates the increasing pollution of surface water courses as they pass from their upper catchments through the urban and agricultural areas before joining the main river within the plain to the north of Bursa.

2.4 Flow Regimes

The seasonal pattern of flows in the Nilufer and its tributaries changes with the altitude of the gauging station. At 3-55, the Delicay at Godeze, the main flow is between April and June and is associated with runoff from snowmelt higher up the mountain (Figure 2.4.1). The gauges 3-23 (Nilufer at Gumustepe) and 3-28 (Aksu, Golbasi inflows) show the same pattern of runoff, but with significant runoff during the winter months of December to March (Figures 2.4.2 and 2.4.3). At these lower altitudes, winter precipitation is in the form of rainfall rather than snow, so there is more immediate runoff. Figure 2.4.3 also shows the release from the reservoir in terms of the equivalent runoff at gauge 3-27.

The seasonal pattern of runoff at Gecit (EIE gauge 321), is illustrated in Figure 2.4.4 for different periods of time. The post 1982 data are for the period since the Doganci dam was constructed, so flows downstream are influenced by reservoir regulation. This effect may also have been accentuated by a period of lower than average rainfall (see Figure 2.1.2), so these two factors may together be the reason for the lower peaks.

The relationship between rainfall and runoff has been investigated on an annual basis by plotting rainfall for the Bursa meteorological station against runoff at Gecit (EIE gauge 321). Using a raingauge on the plain as an estimate of the precipitation on a catchment that includes Uludag and the surrounding mountains is clearly a major assumption. Nevertheless the plot (Figure 2.4.5) demonstrates the type of relationship that would be expected.

The cumulative frequency distribution of daily mean flows, or flow duration curve (FDC), is a convenient measure for describing the complete range of flows from the dry to the flood season. For example the 95 percentile discharge is exceeded on average for 347 (365 x 0.95) days in a year; conversely on all but 18 days in the year the discharge will be lower.

A flow duration analysis has been carried out using the daily flow data for the EIE gauge 321 at Gecit. Three periods have been used: the complete record; the record up to the opening of Doganci dam; and the period since then. The analysis has been carried out on annual data, and also on dry season data where the dry season is defined as extending from July to November inclusive.

Examples of the flow duration curves are shown in Figures 2.4.6 and 2.4.7; the results of all the analyses are shown in Table 2.4.1. The curve shown Figure 2.4.6 is a FDC calculated from all the data; Figure 2.4.7 was based on dry season data. Table 2.4.1 summarises the main statistics from the curves; both the whole year and the dry season analysis show slight increases in low flow percentile for the period since impounding of the Doganci reservoir started. There is no policy of compensation release from the reservoir to maintain flows downstream, so the most likely cause for this small rise in low flows is that as more water is supplied through the distribution system to urban households and industry, there is a corresponding increase in the discharge of waste water back into the river.

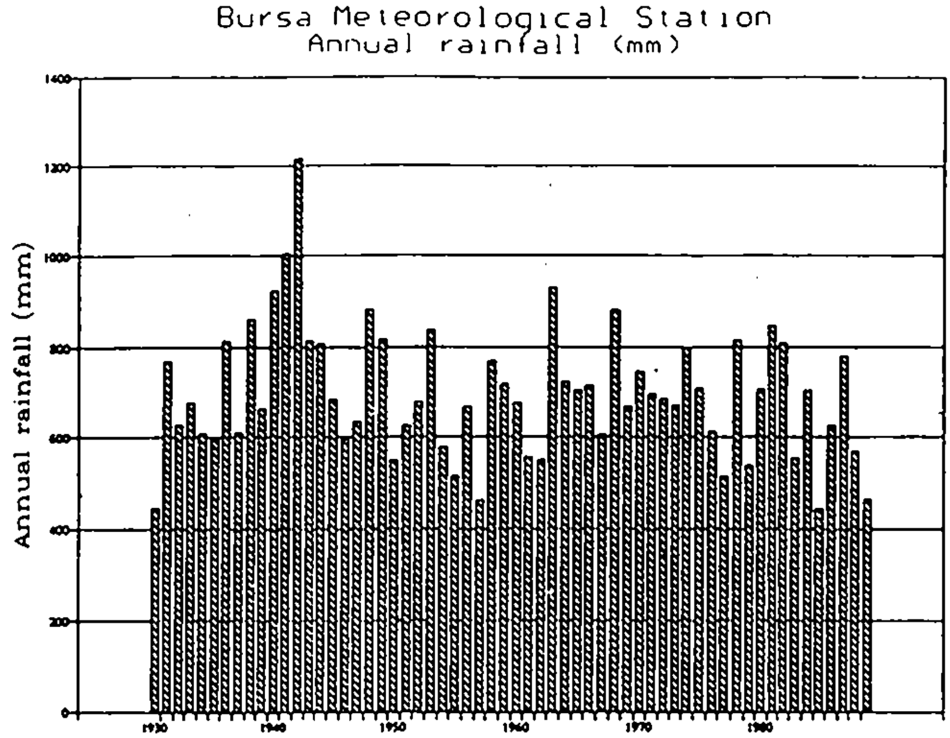


Figure 2.1.1

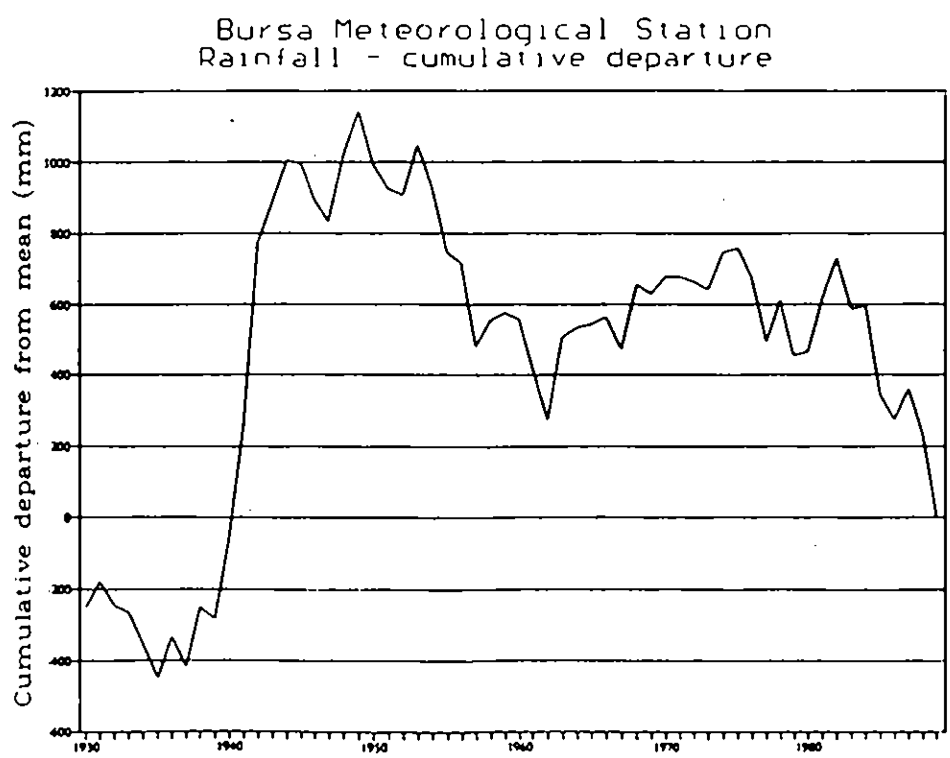


Figure 2.1.2

Location of gauging stations

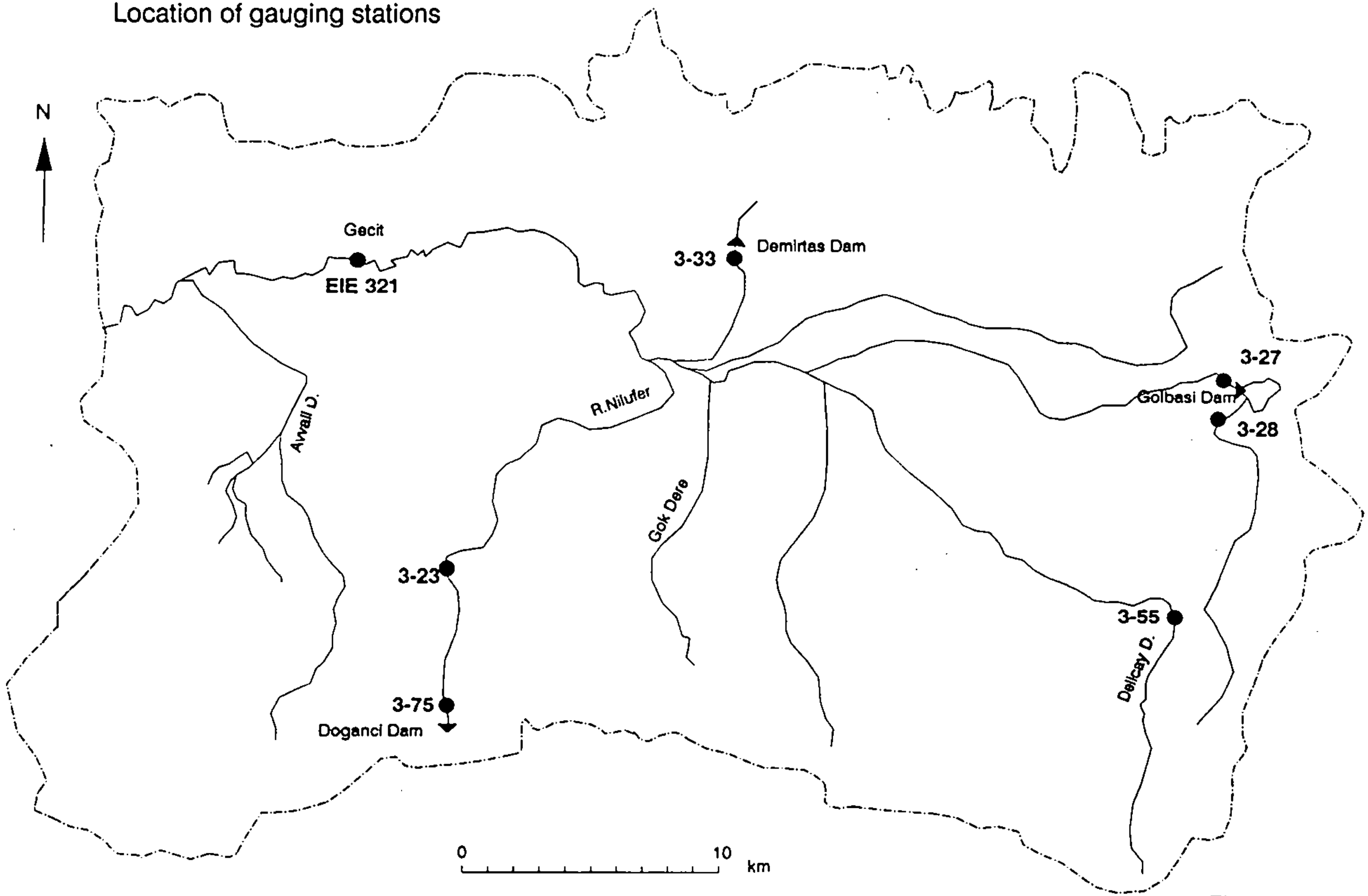


Figure 2.2.1

Table 2.1.1 Rainfall statistics for Bursa (1931-1980)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean monthly rainfall (mm	92	78	74	61	52	30	25	20	41	59	81	108	720
Average number of raindays	15.7	14.3	12.8	11.9	9.2	5.8	3.2	3.0	4.8	8.8	11.7	14.6	115.7
Maximum daily fall (mm)	57.6	55.9	39.8	38.7	49.2	42.2	200.9	68.9	103.2	71.5	78.1	89.2	

Source: DSI Report, Bursa - Demirtas Baraji Planlama Raporu.

Table 2.2.1 Streamflow gauges in the project area

	Number	Location		Altitude m	Catchment Area (km^2)	Period of Record
DSI						
	3-23	Nilufer	Gumustepe	155	474.7	1969 - 1982
	3-27	Golbasi Lake	Outflows	119	64.3	1969 - 1990
	3-28	Aksu Do	Golbasi inflows	151	50.7	1969 - 1990
	3-33	Ballikaya D.	Kelesen	124	45.7	1976 - 1978
	3-38	Kirkpinarlar D.	Uludag	167	8.3	1972 - 1990
	3-44	Doganci Res. inflow	Doganci Res. inflow	341	286.4	1982 - 1990
	3-55	Delicay	Godeze	626	34.6	1983 - 1990
	3-56	Sultaniye	Sultaniye	291	44.0	1982 - 1990
	3-75	Nilufer	Doganci outflow	250	446.8	1984 - 1990
EIE						
	321	Nilufer	Gecit	63	1290.8	1953 - 1989

Location map of water quality sampling points

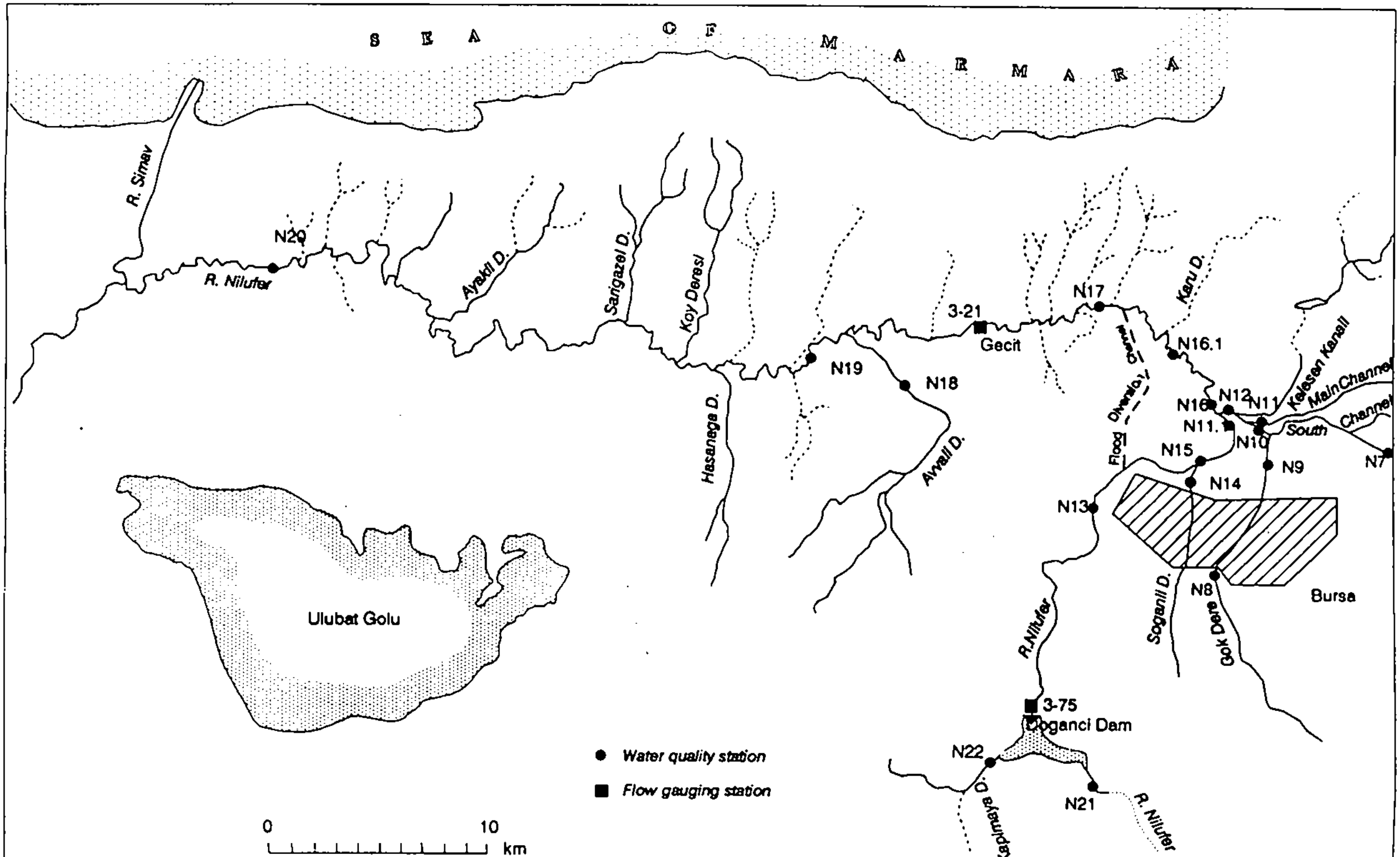


Figure 2.3.1

Delicay at Godeze (3-55)
Average runoff (1983-1989)

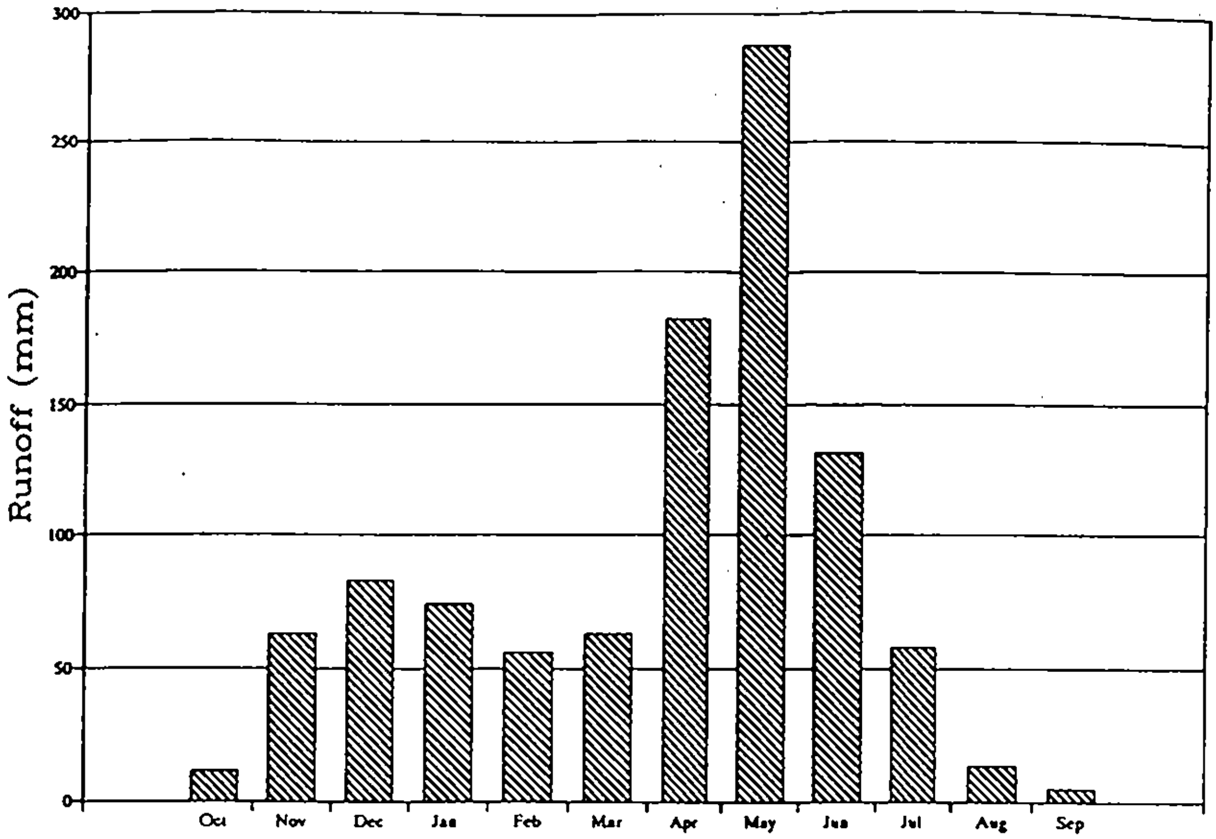


Figure 2.4.1

Nilufer at Gumustepe (3-23)
Average runoff (1969-1982)

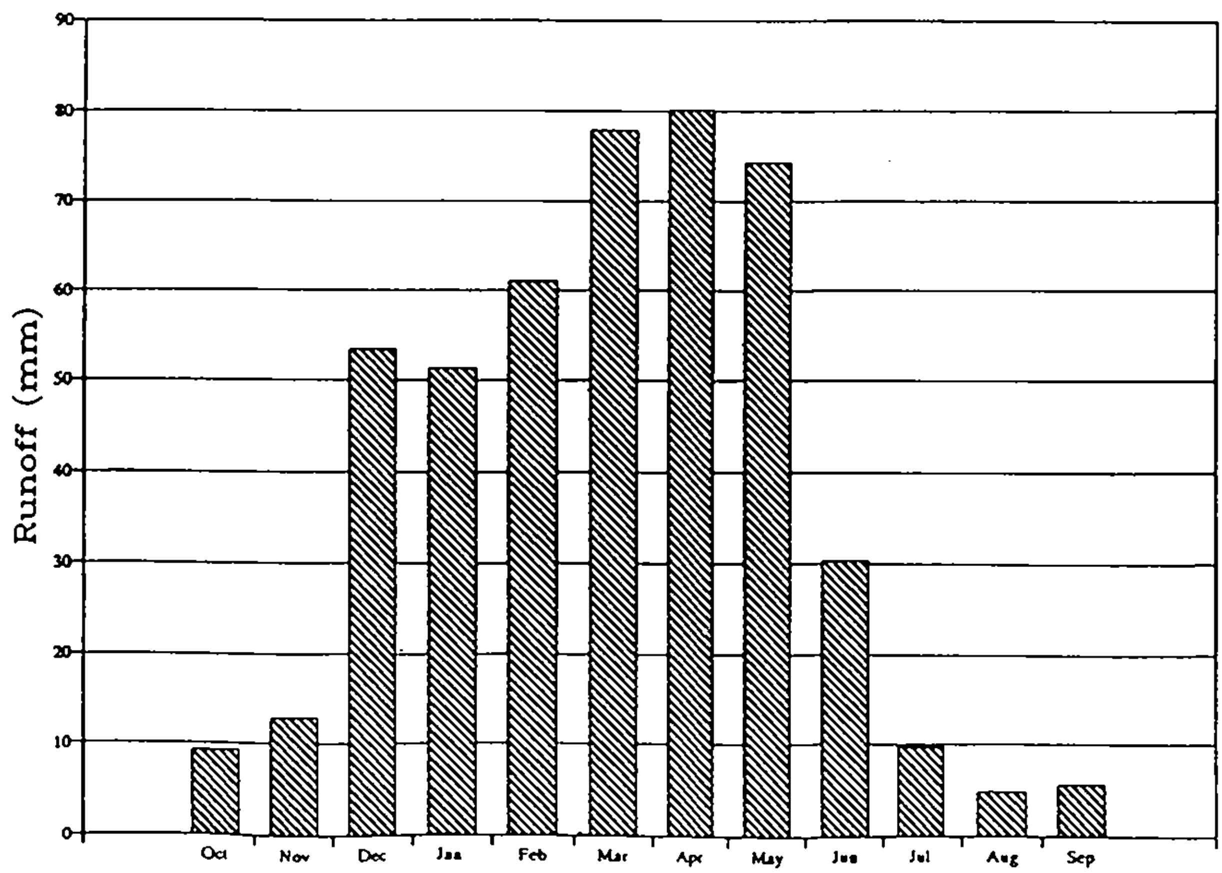


Figure 2.4.2

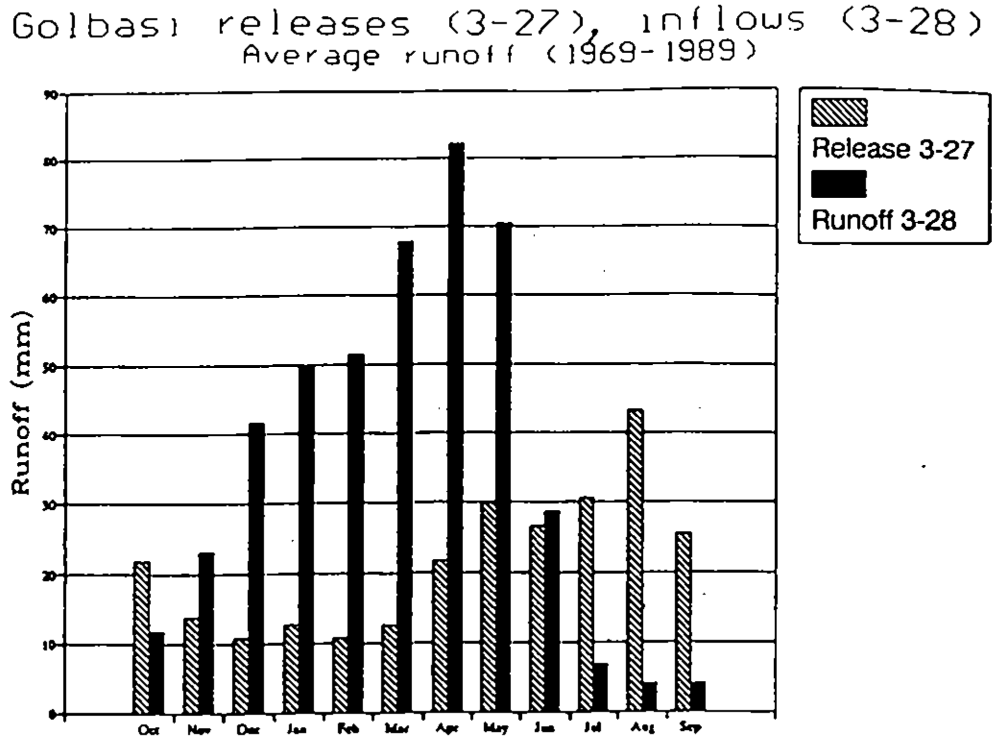


Figure 2.4.3

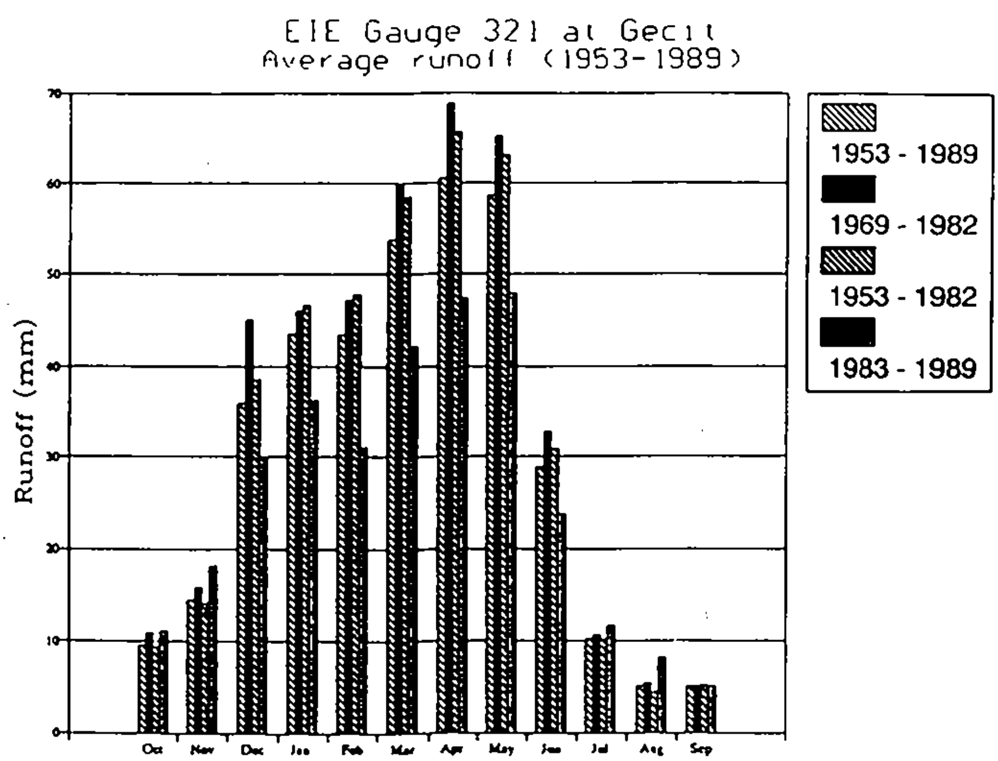


Figure 2.4.4

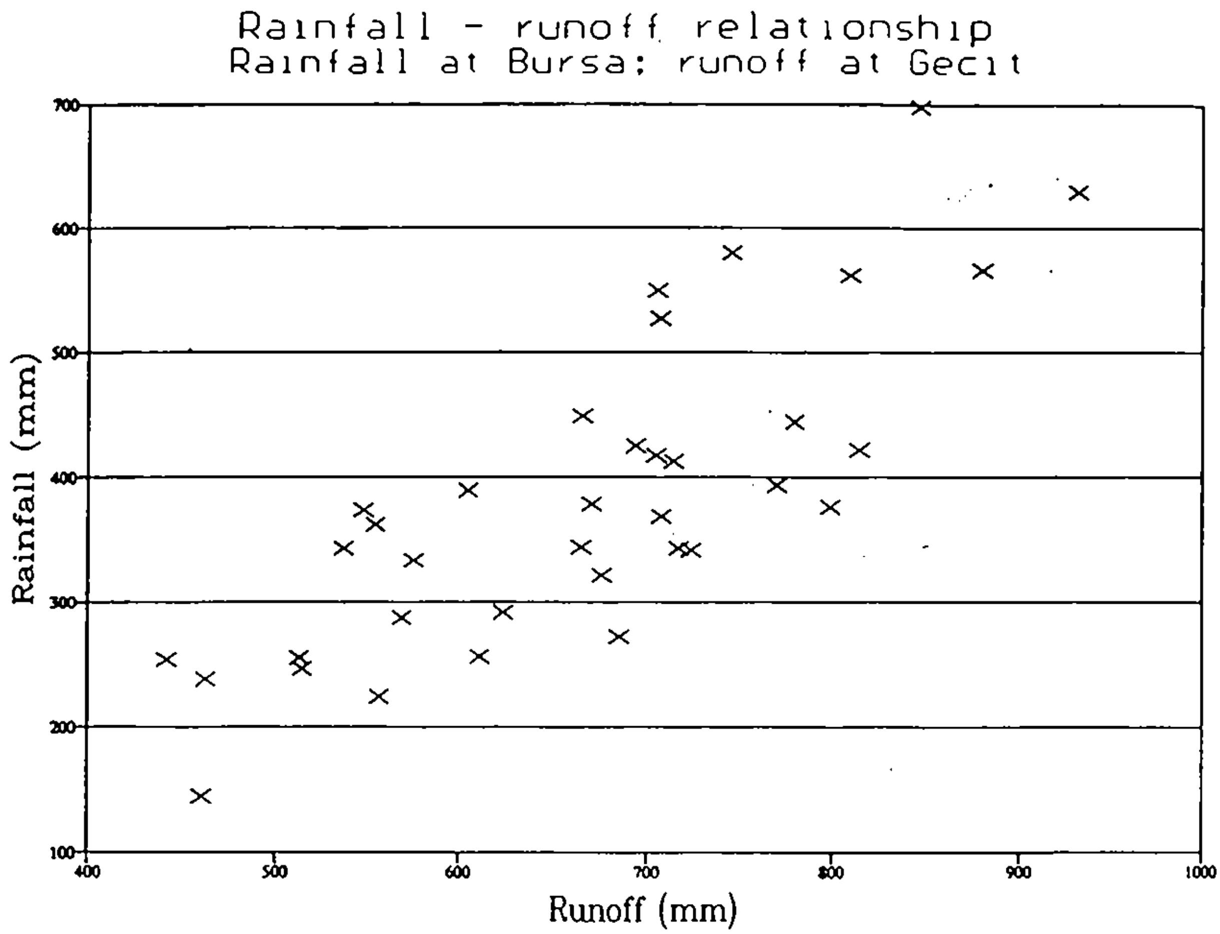

Rainfall - runoff relationship
Rainfall at Bursa; runoff at Gecit
Rainfall (mm)
Runoff (mm)
700
600
500
400
300
200
100
400
500
600
700
800
900
1000

Figure 2.4.5

EIE Gauge 321
Flow duration curve based on annual data

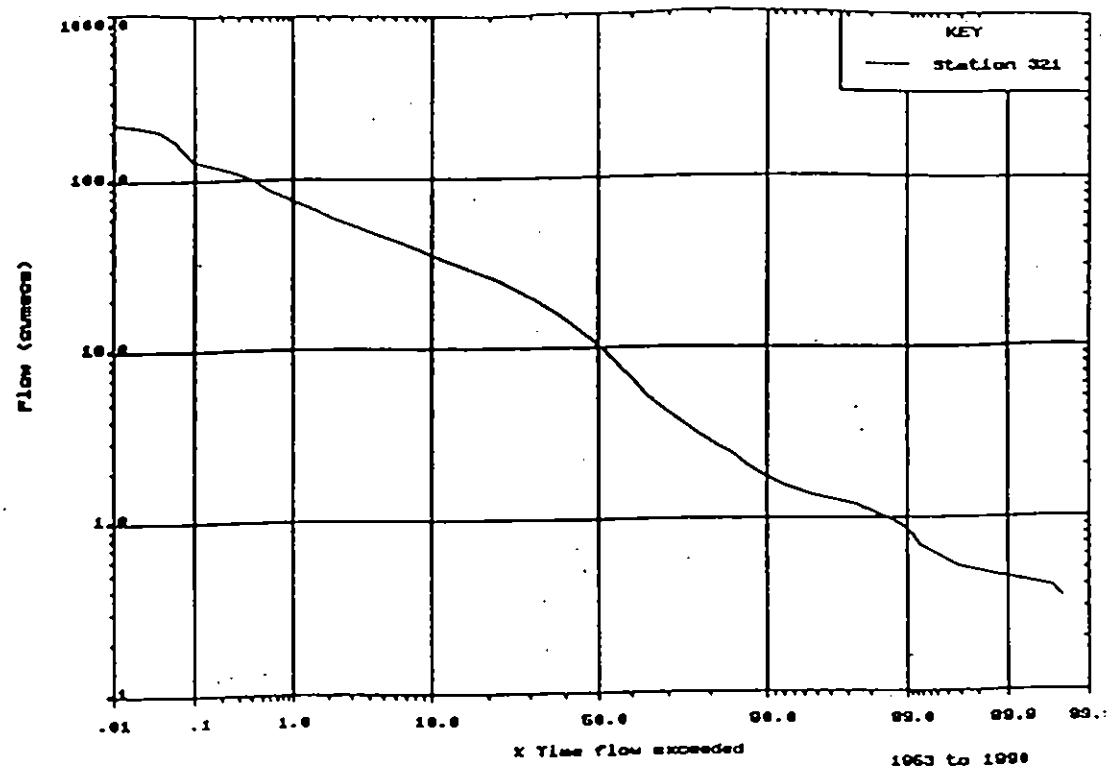


Figure 2.4.6

EIE Gauge 321
Flow duration curve based on dry season data

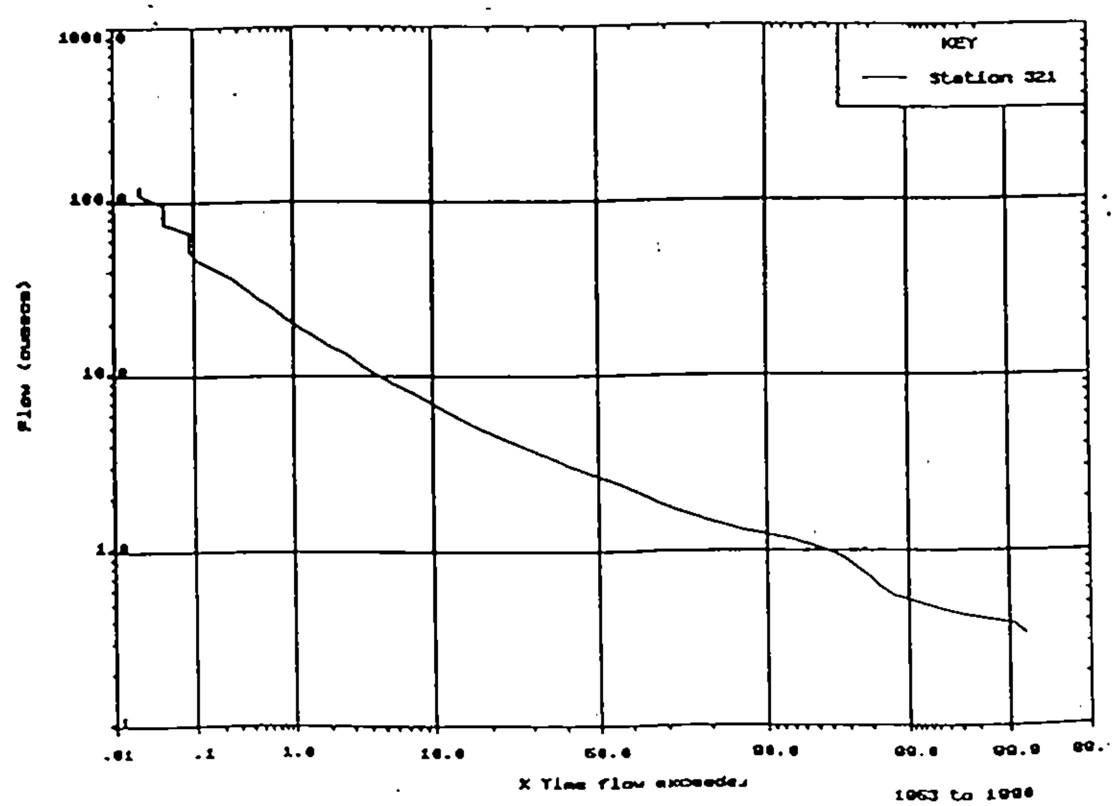


Figure 2.4.7

Table 2.4.1 Flow duration table: EIE Gauge 321 at Gecit

Period	Average daily flow (m^3sec^{-1})	Flow percentiles (m^3sec^{-1}) 95	90	75	50	25	10	5
ANNUAL								
Oct 1953 - Sept 1990	15.57	1.34	1.74	3.43	10.41	22.90	35.42	45.58
Oct 1953 - Sept 1984	16.28	1.32	1.69	3.38	10.02	24.16	37.36	47.56
Oct 1984 - Sept 1990	11.90	1.51	2.07	3.70	8.45	17.67	25.66	29.47
DRY SEASON (July to November)								
Oct 1953 - Sept 1990		1.10	1.27	1.80	3.00	4.96	8.47	12.32
Oct 1953 - Sept 1984		1.08	1.27	1.75	2.97	4.91	8.44	12.17
Oct 1984 - Sept 1990		1.24	1.50	2.20	3.35	4.96	8.66	13.09

3 WATER QUALITY

3.1 Current Water Use

The water resources of Bursa can be considered in three main categories; surface water, springs and groundwater.

3.1.1 Surface Water

There are three main surface water reservoirs in the study area: Doganci reservoir located on the Nilufer River some 15 km south-west of Bursa; Golbasi reservoir which feeds the agricultural area to the east of Bursa; and Demirtas reservoir some 10 km to the north of Bursa. The locations of these reservoirs are shown in Figure 2.2.1; the characteristics of each reservoir are summarised in Table 3.1.1.

The main water supply to Bursa is from the Doganci reservoir which feeds a treatment works at Dobruca. At present the available storage is barely able to meet demands over the dry period from July to October, so a second dam has been planned for a site upstream of Doganci.

The current operating policy assumes that the reservoir will be full at the beginning of July. Water levels during the winter months January to April are kept low to allow some storage for flood control. There appears to be no formal policy for compensation releases to maintain flows in the Nilufer downstream, though there will be releases to the river when the reservoir is full and inflows exceed transfers to the treatment works during the winter. Once the second Doganci reservoir is built, more water will be stored upstream so the overall releases to the river are expected to fall still further.

The Golbasi reservoir is used primarily for irrigation water supply in the alluvial plain to the east of Bursa. It is understood that the Demirtas reservoir was originally intended as an irrigation reservoir, however there are pressures for the water to be used for the industrial complexes located immediately downstream of the dam. In the time available for the study, it was not possible to obtain any further details of the operating policies of these three storage reservoirs.

3.1.2 Springs

The springs from the limestone of the foothills of Uludag have for many years provided water for Bursa. The springs are generally clear and clean, but there tends to be an increase in turbidity after periods of rainfall. At present it is estimated that the discharge of natural springs into Bursa is over 650 l/sec.

3.1.3 Groundwater

There are water bearing formations in the plains to the east and north of Bursa. DSI have undertaken detailed hydrogeological studies; the 1973 report concluded that the Bursa aquifer might yield over 115×10^6 m^3 $year^{-1}$. At present there are two wellfields that can be used to provide an emergency supply for Bursa.

Groundwater is also used for irrigation is the Bursa plain; many of the industrial complexes also have their own borehole supplies.

3.2 Existing Water Quality

The existing quality of surface waters in the basin is illustrated by the summary statistics for selected DSI sampling points that are shown in Table 3.2.1. The sampling points are divided into three groups: mountain sample points, upstream sample points, and downstream sample points.

Sampling points N21 and N22, among others, are used by DSI to monitor the quality of reservoir inflows. The data indicate that these mountain watercourses are relatively unpolluted, with high dissolved oxygen (DO) and low biochemical oxygen demand (BOD). However some high E. Coli measurements indicate that pollution from upstream villages can sometimes be a problem.

Sampling points in the upstream group (N1, N8 and N13) are at a lower altitude but are all upstream of the main urban area of Bursa. Nevertheless the table shows a decline in water quality, particularly in the dry season when dilution is small. BOD is higher, and there are samples with high E.Coli counts.

Sampling points in the third group (N9, N11 and N14) are further downstream where rivers, channels and drains flow out of the urban area. The effects of untreated outfalls are clear; dissolved oxygen is reduced and in some cases falls to zero. BOD and chloride have increased; with the exception of N11, all the sample points indicate gross pollution from sewage outfalls upstream.

The quality of these surface water courses does change over the seasons; typical graphs for dissolved oxygen and BOD are shown in Figures 3.2.1 to 3.2.4. Highest concentrations of BOD and lowest DO levels tend to occur at the end of the dry season (October/November) through to January/February. During this period flows are initially low so that there is little dilution of the effluent discharges. Higher rainfall results in increased flow, but this causes residual pollution in many of the dry water courses to be flushed into the system. DO concentrations tend to decrease when moving downstream (N13 to N16 to N17 to N19), together with the number of samples with zero DO concentrations. The graphs show no obvious trend over time.

It should be remembered that only spot samples are taken, at a frequency of every two months or so. It is likely that river water quality will deteriorate dramatically within the space of just a few hours when particular industrial processes are operating and discharging effluents at a high rate. Such pollution events could be completely missed by the present sampling procedures. Consequently it is likely that extremely poor water quality can occur at any time of the year.

Within the DSI sampling programme there is no routine testing for heavy metals. Samples taken as part of this study indicated high concentrations of lead, nickel, zinc, chromium and copper in the river downstream of Bursa.

3.3 River Quality Objectives

River Quality Objectives (RQO) are environmental objectives for surface water courses which can be set for different end uses of the water. Associated with RQO's are chemical criteria, or Environmental Quality Standards, which should be achieved if the river is to be suitable for its intended use.

For the Nilufer, one of the key steps is to define the objectives of providing treatment to direct discharges to the river. In Bursa, the prime reason is to prevent public health nuisance and smell, whereas on other rivers the objective might be to ensure that water is suitable for abstraction for public supply downstream. The scale of what has to be achieved may be very different in each case, but for each an objective has to be established. A water quality objective defines the use, or uses, for which a body of water must be suitable.

For some variables, the objectives can be expressed in terms of 95 percentile; the objective then requires that on average 95 percent of the samples should have a quality better than the 95 percentile value. In the case of dissolved oxygen, this means higher values; for BOD and chemical pollutants lower values are required. Setting objectives in terms of percentiles acknowledges the inherent variability of river systems, and has been found in many countries to be a suitable approach.

Water quality objectives have been defined for rivers in Turkey; the values of main determinands used in QUASAR for the various river quality classes are shown in Table 3.2.2. At present many of the surface waters downstream of the Doganci dam would fall into the Class IV, or very polluted, category. A first stage objective would be to reduce pollution from the major outfalls so that the stretches of the river can be assigned to a less polluted class.

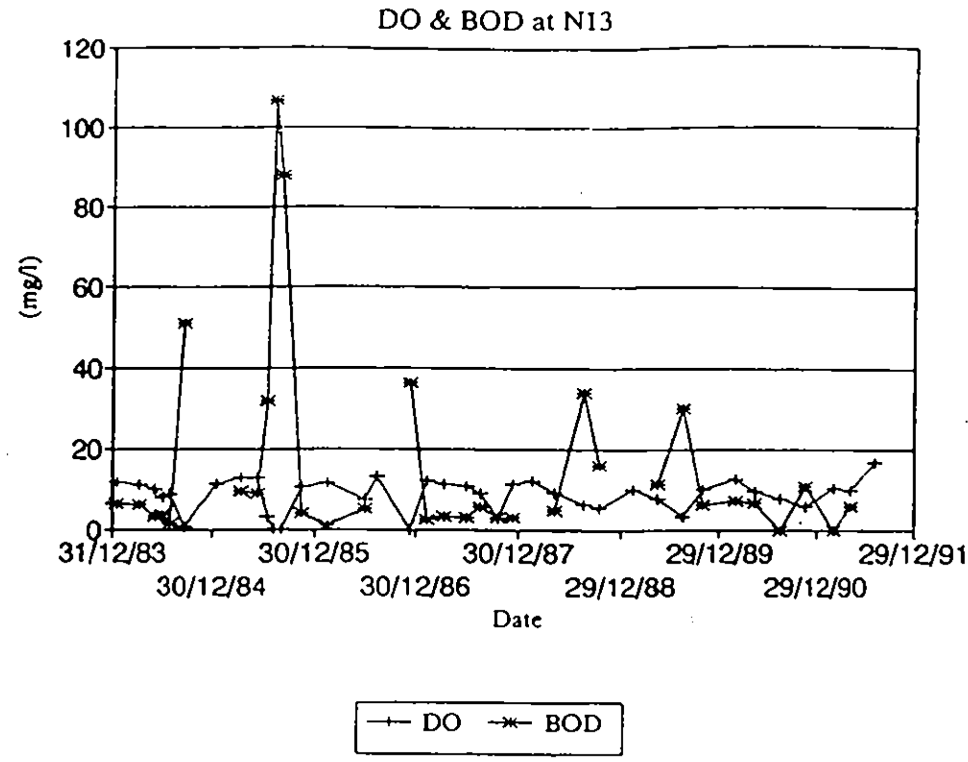


Figure 3.2.1

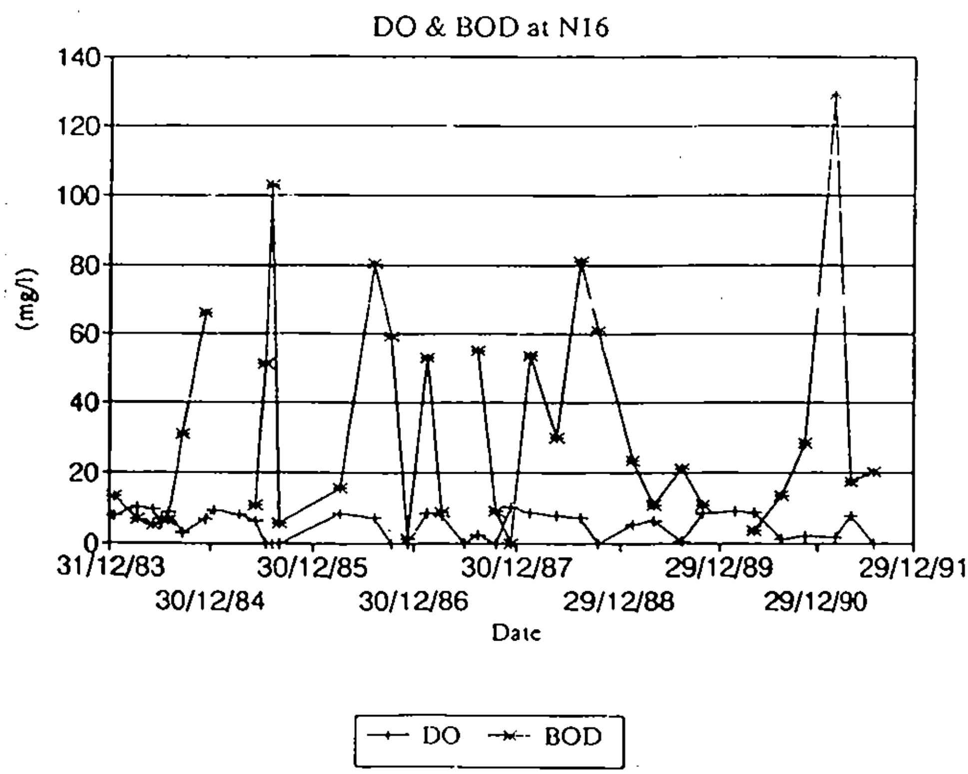


Figure 3.2.2

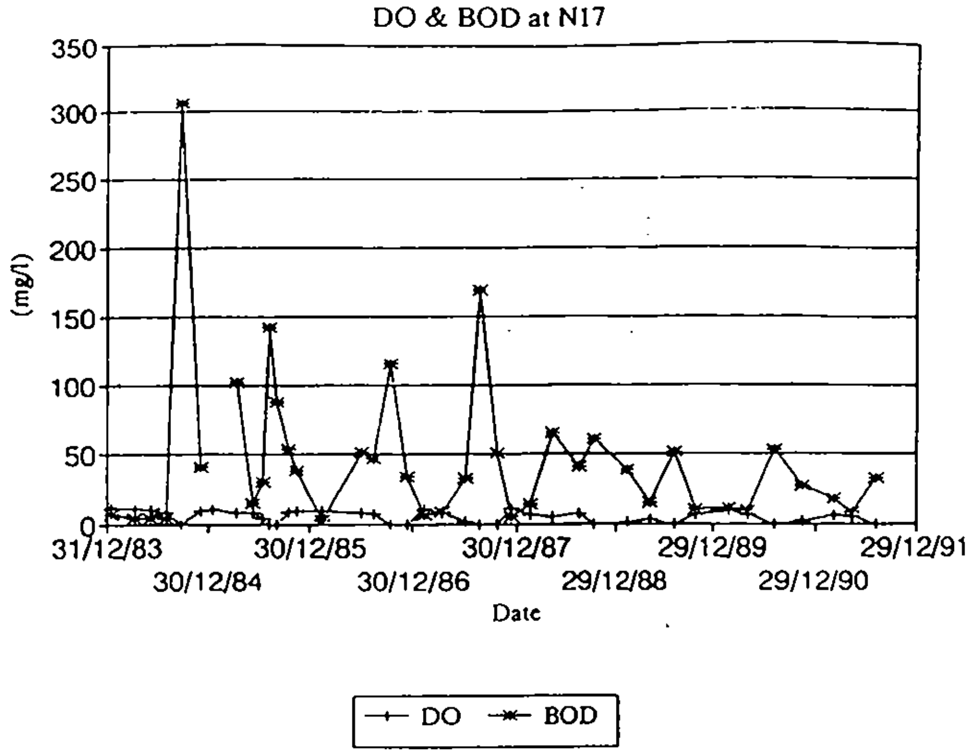


Figure 3.2.3

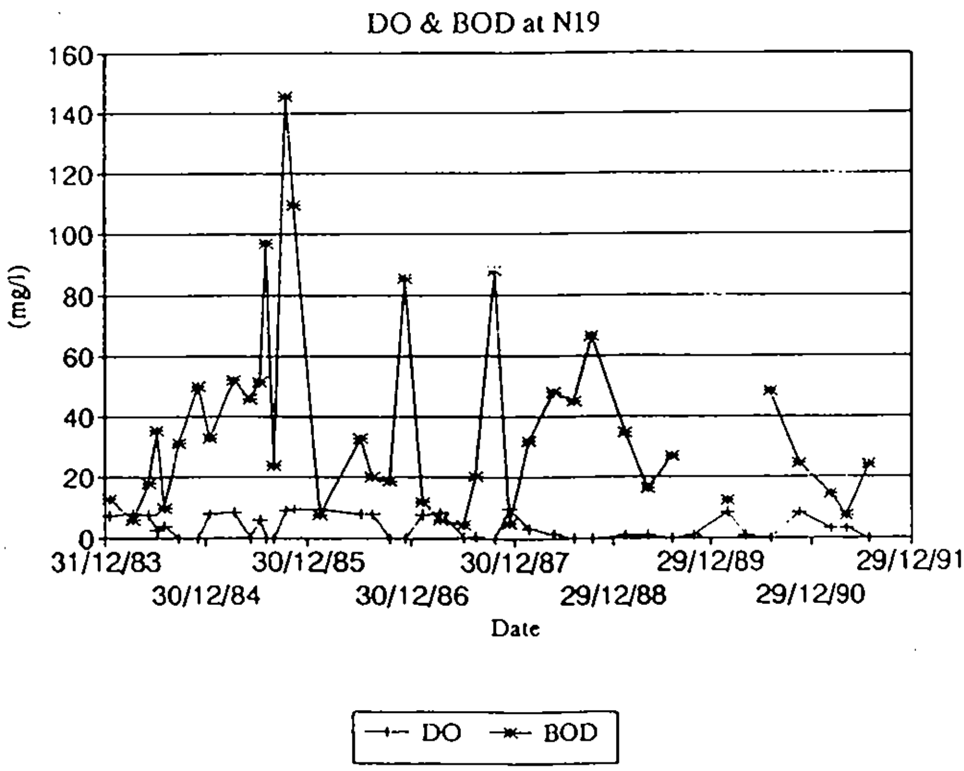


Figure 3.2.4

Table 3.1.1 Characteristics of Surface Reservoirs

	Catchment Area (km^2)	Average Inflow	Live Storage	Year Impounded
		(m^{3}x10^6)	(m^{3}x10^6)	
Doganci Reservoir+	450	175.6	25.6	1984
Golbasi Reservoir++	98	47.9	34.2	1973
Demirtas Reservoir+++			13.4	1987

\+ Doganci Baraji : Muhendislik Hidrolojisi Ozeti, DSI, 1987
++ Bursa - Golbasi Projesi Planlma Raporu, DSI, 1985
+++ Bursa - Demirtas Baraji Planlama Raporu, DSI.

Table 3.2.1 Summary statistics of DSI Water Quality Data (1984-1991)

I - MOUNTAIN SAMPLE POINTS

DSI Gauge N21; Baraf Memba

	FLOW (m3s-1)	NO3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH3(N) (mg/l)	H2O TEMP (C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	5.12	0.5	7.3	10.1	2.9	1.4	14.5	2518	8.3
SD:	5.16	0.6	3.7	1.9	3.1	4.4	6.9	7422	0.3
Max	16.00	3.4	17.0	15.6	17.4	20.8	24.0	39000	8.9
Min	0.01	0.0	2.3	5.8	0.4	0.0	3.0	3	7.5
WET SEASON									
Mean:	7.26	0.5	5.7	11.1	3.3	0.2	10.3	3338	8.3
SD:	4.63	0.3	2.3	1.5	3.5	0.3	5.3	9149	0.3
DRY SEASON									
Mean:	1.64	0.4	9.3	8.8	2.2	2.7	19.0	1357	8.3
SD:	3.77	0.8	4.1	1.6	2.4	6.4	5.1	2868	0.3

DSI Gauge N22; Sultanyie Kolu

	FLOW (m3s-1)	NO3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH3(N) (mg/l)	H2O TEMP (C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	0.42	0.4	6.6	9.9	2.0	0.3	12.3	1307	8.1
SD:	0.58	0.5	2.2	1.9	1.4	0.3	5.5	2700.70	0.3
Max	2.60	3.0	11.3	13.6	5.6	1.6	24.0	12300	8.8
Min	0.00	0.0	2.3	3.1	0.1	0.0	0.0	0	7.2
WET SEASON									
Mean:	0.68	0.3	6.1	10.8	2.1	0.2	9.7	819	8.2
SD:	0.63	0.2	2.1	1.3	1.3	0.3	5.2	1933	0.3
DRY SEASON									
Mean:	0.06	0.4	7.3	8.8	2.0	0.4	15.5	1999	8.0
SD:	0.11	0.7	2.2	1.9	1.5	0.3	4.1	3394	0.3

II - UPSTREAM SAMPLE POINTS

DSI Gauge N1; Golbazi Aksu Dere Mansap

	Flow (m3s-1)	NO_3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH_3(N) (mg/l)	Water temp (°C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	0.57	0.6	10.4	10.5	3.0	0.4	10.7	4479	8.2
SD:	0.49	0.5	7.5	2.1	2.4	0.6	5.7	3851	0.2
Max	1.76	1.9	45.1	13.9	11.4	2.6	24.0	13000	8.8
Min	0.00	0.1	4.5	2.8	0.6	0.0	0.5	100	7.8
WET SEASON									
Mean:	0.66	0.5	8.5	10.5	2.8	0.4	10.2	3740	8.2
SD:	0.49	0.4	2.0	2.3	1.8	0.6	6.0	3043	0.2
DRY SEASON									
Mean:	0.18	0.8	16.3	10.6	3.9	0.4	12.2	4217	8.2
SD:	0.21	0.6	12.9	0.8	3.5	0.4	3.7	4733	8.2

DSI Gauge N8; Gokdere Memba

	FLOW (m3s-1)	NO3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH3(N) (mg/l)	H2O TEMP (C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	0.55	0.2	27.0	8.1	44.0	7.4	13.7	32423	7.9
SD:	0.54	0.3	31.6	4.0	61.0	16.3	6.8	30504	0.3
Max	1.93	1.4	138.0	13.0	196.0	81.5	27.0	92000	8.6
Min	0.03	0.0	4.7	0.0	1.0	0.0	3.0	3000	7.4
WET SEASON									
Mean:	0.70	0.2	15.1	9.5	26.7	2.3	11.3	30770	7.9
SD:	0.57	0.3	11.9	2.7	47.6	3.7	5.7	30444	0.3
DRY SEASON									
Mean:	0.23	0.2	50.8	5.3	78.5	17.6	18.6	28450	7.8
SD:	0.24	0.3	42.0	4.5	67.0	24.3	5.9	26734	0.4

DSI Gauge N13; Abdal Koprusu

	FLOW (m3s-1)	NO3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH3(N) (mg/l)	H2O TEMP (C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	3.46	0.4	18.8	8.6	16.7	5.3	17.6	553240	8.1
SD:	4.52	0.4	21.0	4.2	24.9	9.5	8.3	740059	0.3
Max	16.45	1.7	108.7	16.9	106.8	46.5	32.0	2700000	8.8
Min	0.03	0.0	0.1	0.0	1.0	0.0	5.0	10000	7.7
WET SEASON									
Mean:	4.44	0.6	12.2	10.4	7.4	1.6	12.4	209714	8.1
Sd:	4.18	0.4	12.3	2.7	8.0	2.4	5.7	231211	0.3
DRY SEASON									
Mean:	2.14	0.2	33.1	6.6	24.9	9.4	23.3	990455	8.1
Sd:	4.38	0.2	25.6	4.4	31.1	12.2	6.7	886321	0.3

III - DOWNSTREAM SAMPLE POINTS

DSI Gauge N9 Gokdere Mansap

	FLOW (m3s-1)	NO3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH3(N) (mg/l)	H2O TEMP (C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	0.86	0.4	45.5	5.6	106.4	11.0	15.5	5144444	7.8
SD:	0.63	0.5	25.7	3.8	73.8	12.2	6.0	5872555	0.3
Max	2.63	2.4	128.8	11.8	303.5	60.8	27.5	21000000	8.6
Min	0.27	0.0	11.8	0.0	5.0	0.6	6.0	99999	7.3
WET SEASON									
Mean:	1.08	0.6	36.1	7.2	97.8	7.2	12.3	2510000	7.9
SD:	0.70	0.6	23.7	3.3	78.9	6.3	4.5	1718191	0.3
DRY SEASON									
Mean:	0.53	0.3	58.9	3.5	114.4	16.5	20.0	7500000	7.8
SD:	0.20	0.3	21.7	3.4	64.4	16.0	4.7	7457955	0.2

DSI Gauge N11; Ana Tahliye Kanali

	FLOW	NO3(N)	Cl	DO	BOD	NH3(N)	H2O TEMP	E.Coli	pH
	(m3s-1)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(C)	(Nr/100cc)	
OVERALL									
Mean:	0.89	1.0	15.4	10.3	6.2	2.3	16.0	632	8.0
SD:	1.14	0.9	9.4	3.1	18.9	7.2	7.2	1223	0.4
Max	6.08	3.8	60.1	17.6	121.8	45.8	27.0	5200	9.2
Min	0.04	0.0	1.5	2.3	0.5	0.0	3.0	10	7.3
WET SEASON									
Mean:	1.29	1.2	16.1	11.6	3.4	1.1	12.8	991	8.0
SD:	1.38	1.0	9.9	2.7	2.5	1.0	6.8	1636	0.3
DRY SEASON									
Mean:	0.42	0.7	14.5	8.7	9.5	3.7	19.9	313	8.0
SD:	0.30	0.8	8.5	2.8	27.3	10.3	5.3	247	0.4

DSI Gauge N14; Soganli Dere Karizim Sonrasi

	FLOW	NO3(N)	Cl	DO	BOD	NH3(N)	H2O TEMP	E.Coli	pH
	(m3s-1)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(C)	(Nr/100cc)	
OVERALL									
Mean:	0.72	0.2	80.5	3.7	155.3	18.5	16.8	9741667	7.8
SD:	0.43	0.3	60.0	3.4	79.4	28.6	4.6	12726312	0.3
Max	2.67	1.5	296.8	9.3	411.0	161.6	24.5	46000000	8.8
Min	0.23	0.0	1.9	0.0	1.5	0.6	9.5	1400000	7.2
WET SEASON									
Mean:	0.87	0.2	70.4	4.9	162.2	12.7	14.6	11016667	7.9
SD:	0.50	0.3	30.1	3.1	91.8	12.2	4.5	15764350	0.3
DRY SEASON									
Mean:	0.54	0.2	91.8	2.3	148.4	25.0	19.3	8466667	7.7
SD:	0.18	0.2	78.4	3.1	60.3	38.0	2.9	6720036	0.3

DSI Gauge N18; Ayvali Dere Mansap

	FLOW (m3s-1)	NO3(N) (mg/l)	Cl (mg/l)	DO (mg/l)	BOD (mg/l)	NH3(N) (mg/l)	H2O TEMP (C)	E.Coli (Nr/100cc)	pH
OVERALL									
Mean:	1.17	0.3	225.5	3.2	170.5	8.7	19.4	339353	8.3
SD:	1.60	0.4	215.4	3.8	147.4	16.3	7.9	708563	0.6
Max	5.86	1.3	782.5	9.5	661.0	79.5	33.5	3000000	9.3
Min	0.02	0.0	11.5	0.0	3.5	0.1	5.5	10000	7.2
WET SEASON									
Mean:	2.00	0.4	182.1	4.1	170.0	3.7	15.3	125200	8.3
SD:	1.87	0.4	197.2	3.7	190.5	4.5	7.7	132861	0.5
DRY SEASON									
Mean:	0.40	0.2	271.6	2.3	170.9	13.7	23.4	564625	8.3
SD:	0.54	0.2	217.6	3.5	87.2	21.1	5.3	942538	0.7

Table 3.2.2 ***Selected Water Quality Criteria for Inland Waters According to their classes***

		Water Quality Classes			
		I	II	III	IV
	WATER QUALITY VARIABLES				
a)	PHYSICAL AND INORGANIC CHEMICAL VARIABLES				
	Temperature (°C)	25	25	30	≥30
	pH	6.5 - 8.5	6.5 - 8.5	6.0 - 9.0	6.0 - 9.0
	Dissolved oxygen (mg/l)	8	6	3	<3
	Dissolved oxygen (% saturation)	90	70	40	<40
	Chloride (mg/l)	25	200	400	>400
	Ammonium (mg(N)/l)	0.2	1	2	>2
	Nitrate (mg/l)	5	10	20	>20
b)	ORGANIC VARIABLES				
	Biochemical oxygen demand (mg/l)	4	8	20	>20
d)	BACTERIOLOGICAL				
	Faecal coliforms E. Coli (nr/100 ml)	10	200	2000	>2000

Taken from: Resmi Gazette 4 Eylul 1988 - Sayi: 19919, Sayfa : 39

c) Inorganic pollution parameters not included in this summary table.

Class I high quality water
II fairly polluted water
III polluted water
IV very polluted water

4 WATER QUALITY MODEL

4.1 Model Structure

The water quality modelling exercise was carried out using the dynamic flow and water quality model QUASAR (QUAlity Simulation Along Rivers) developed at the Institute of Hydrology to assess the impact of pollutants on river systems. QUASAR can be used to investigate a wide range of inputs including tributaries, groundwater inflows, direct runoff, effluents and storm water. The model can also allow for abstractions for public supply or irrigation. More details of QUASAR are given in Appendix 1.

QUASAR can operate in two modes - dynamic and planning - both of which have been used for the present study. In the dynamic mode, the model simulates flow and water quality over selected periods, and requires time series of flow and water quality as input data. Predictions of water quality at various points downstream are then made. The dynamic mode was used to calibrate QUASAR for the Nilufer; the calibrated model was then used in planning mode to investigate alternative designs for sewage treatment works.

In planning mode, QUASAR generates a cumulative frequency distribution of selected water quality variables for a given set of hydrological and water quality inputs and specified operating criteria for the sewage treatment works. The flow and quality of the modelled tributaries, and direct and indirect discharges are defined as statistical distributions. QUASAR then takes samples at random from the selected distributions in order to provide the input data needed for the model run. The sampling procedure is repeated many times so that cumulative frequency distributions of flow and quality can be calculated. The process is known as Monte Carlo simulation. The output data generated in this mode can help to set consent standards, and to formulate river quality objectives.

The reach structure used to represent the Nilufer and its tributaries downstream of Doganci reservoir is illustrated in Figure 4.1.1; details of the individual reaches are given in Table 4.1.1.

The Doganci dam defines the upstream end of the model; moving downstream, reach boundaries were selected at points where major tributaries or drainage canals join the main river. An additional criteria was that only one major effluent should flow into each reach. The major drainage network from the east which feeds into the Nilufer north of the city has been included as a separate tributary network. The flood diversion canal was also included explicitly in the model structure.

Downstream of the EIE gauge at Gecit, other major tributaries were also included. Of particular importance is the Avvali D., a left bank tributary which would collect the effluent from the proposed industrial sewage treatment works to the west of the city.

It would in theory be possible to define a more complex reach structure to include various tributaries and drainage canals in more detail, however the complexity of the network modelled has to be balanced against the availability of flow and water quality data.

As noted in Section 2.3, the collection of water quality data only started in 1984. Data for the calibration of QUASAR had to be based on data for the period since then; after review of the flow and quality data available it was decided to use data from 1984 to calibrate QUASAR.

4.1.1 Model Inflows

The most complete set of daily flow data is for the EIE gauge number 321 at Gecit, which has a catchment area of 1291 km^2. Outflows from the Doganci reservoir are gauged at DSI 3-75, where the catchment area is 447 km^2. The other tributaries are only gauged in their upper reaches, and therefore provide little additional information for the estimation of flows at points where tributaries join the Nilufer.

At the time that DSI take samples for water quality, flows are also measured. These spot flow measurements were used with the corresponding flow data for gauge 321 to define a simple relationship between the two sets of data. A time series of daily flow data at the sampling site was then calculated from this relationship.

At locations where no water quality, and therefore no flow data are available, flows were estimated by mass balance between appropriate spot sample sites. For example the inflows from the small tributaries to Nilufer reach 2 were estimated as the difference between the flows from Doganci reservoir and the times series of flow at N13 established from the regression equation with EIE gauge 321. Note that in some instances, flows decrease in a downstream direction; this occurs either as a result of taking differences between small numbers or because water is flowing from the river into the groundwater.

QUASAR also requires the relationship between flow and velocity in each reach; where spot flow and corresponding velocity measurements were available, these were used in linear regression analysis to establish a relationship for the reach.

There are no flow monitoring stations downstream of Gecit. Flows from the tributaries downstream of this point, which include the left bank tributary the Avvali D., were estimated from the difference between the spot flow measurements at sampling points N19 and N20. The flows were distributed between the major tributaries in proportion to the contributing catchment area.

4.1.2 Water Quality

For this study, QUASAR was set up to use mean monthly water quality data. For example if a sample had been taken in August 1984, then the results for that sample were used as the August input data for QUASAR. If there was no sample for September in 1984, then the mean values of any September samples taken in 1985 onwards was used as input data. Note that this procedure does not account for any trends in the data over time.

At those locations where water quality data was required by QUASAR, but where no samples had been taken, values from sites assumed to have a similar chemistry were used. The water quality sample points used to represent the flow and water quality inputs to each reach are summarised in Table 4.1.1.

4.1.3 Model Calibration

The purpose of model calibration is to adjust the parameters of the equations that represent the chemical processes in the river, so that the model predictions and observed data match. Flow was calibrated first, since it is fundamental to the mass balance for the quality determinands. A plot of observed and predicted flow is shown in Figure 4.1.2. As to be expected, the plot for Gecit shows good agreement between the observed and predicted values, as many of the tributary inflows were estimated from the data at Gecit (EIE gauge 321) using simple regression relationships. The variation in flow at N20 is shown as Figure 4.1.3; the 4 recorded spot values during 1984 are also plotted.

The least dependent quality variables, ammonia and BOD, were then calibrated. Nitrate and dissolved oxygen (DO) were the last variables to be fitted; DO is controlled by the concentrations of other chemical variables such as BOD, nitrate and ammonia, and is also affected by factors such as reaeration, weir aeration, and photosynthesis.

The various parameters were adjusted until no further improvement in model fit could be achieved. Assessment of model fit was itself very subjective, given the relative lack of flow and quality data for the Nilufer with which to calibrate QUASAR.

4.2 Interpretation of Model Results

Summaries of the output from QUASAR run using dry season data under existing conditions are given in Tables 4.2.1 and 4.2.2. The tables show the main statistics of the distributions of simulated flow and quality variables at each reach of the main river and right bank canal. The dry season flows from upstream are low, so much of the flow is maintained by effluent and drainage from the urban area.

Moving downstream along the Nilufer, Table 4.2.1 illustrates the effect of the Soganli D. and the outfall just downstream; chloride, BOD and E. Coli concentrations show a sharp increase. Dissolved oxygen falls to zero. Table 4.2.2 show similar statistics for the right bank canal. These results illustrate the generally poorer water quality downstream of the urban area, and the main industrial areas. There is a slight improvement in water quality downstream of Avvali D., the last major source of effluent into the river; the model results suggest that the river has some assimilative capacity from this confluence down to the Simavi C.

For the future, two alternative stages of development of sewage treatment works are being considered; anaerobic ponds as a first stage process, and conventional activated sludge as the final process. The effects of implementation of the each type of process have been examined using QUASAR. Effluent discharges projected for the year 2000 have been used for each of two simulations, so the overall flow conditions are comparable. The following different effluent discharges for each works and effluent quality standards have been assumed for each process;

Assumed effluent flow to river in year 2000

	Central STW	Industrial STW
Flow (m^3 sec^{-1})	1.55	0.53

Effluent quality for each process

	Ponds	Activated sludge
BOD (mg l^{-1})	180	20
DO (mg l^{-1})	0	1 to 4
Ammonia (mg l^{-1})	20 to 30	20 to 30
Temperature (° C)	15	15
pH	6 to 7	7

For the purposes of this preliminary analysis, it has been assumed that the direct discharges from other outfalls are reduced by the flow through the proposed treatment works, but that the quality of the untreated effluent remains the same. For those tributaries into which effluents had discharged directly, the flow into the main river was reduced to take account of the flow through the treatment works. It was assumed that the quality in the tributary reverted to the quality of an upland tributary once the effluent was routed to a treatment works.

Table 4.2.3 presents flow and quality statistics for the river reaches calculated by QUASAR under the assumption that domestic effluent is passed through anaerobic ponds at the central treatment works and industrial effluent is routed through anaerobic ponds at the western works. Comparison with Table 4.2.1 clearly shows the effect of reducing the effluent of Soganali D. and passing it through the treatment works, as the increase in BOD now occurs one reach further downstream. The results for dissolved oxygen indicate that the implementation of the anaerobic ponds leads to improvements further downstream. The model predicts that DO will be low at the confluence with the Simavi C., nevertheless there is an improvement over the results for current conditions given in Table 4.2.1.

Table 4.2.4 shows similar results to Table 4.2.3, but under the assumption that the effluent is treated by an activated sludge process at each of the proposed treatment works. The relative improvement in quality, especially in terms of DO and BOD is clear. However the improvement in quality is soon counteracted by the polluted inflow from the right bank channels which join the Nilufer just downstream of N11.1. As to be expected, the model results in Table 4.2.4 for the activated sludge process show a clear improvement in terms of higher dissolved oxygen and lower BOD than the anaerobic ponds. There is a further improvement in dissolved oxygen and BOD in the reaches downstream of the proposed treatment works.

Quasar plan for River Nilufer

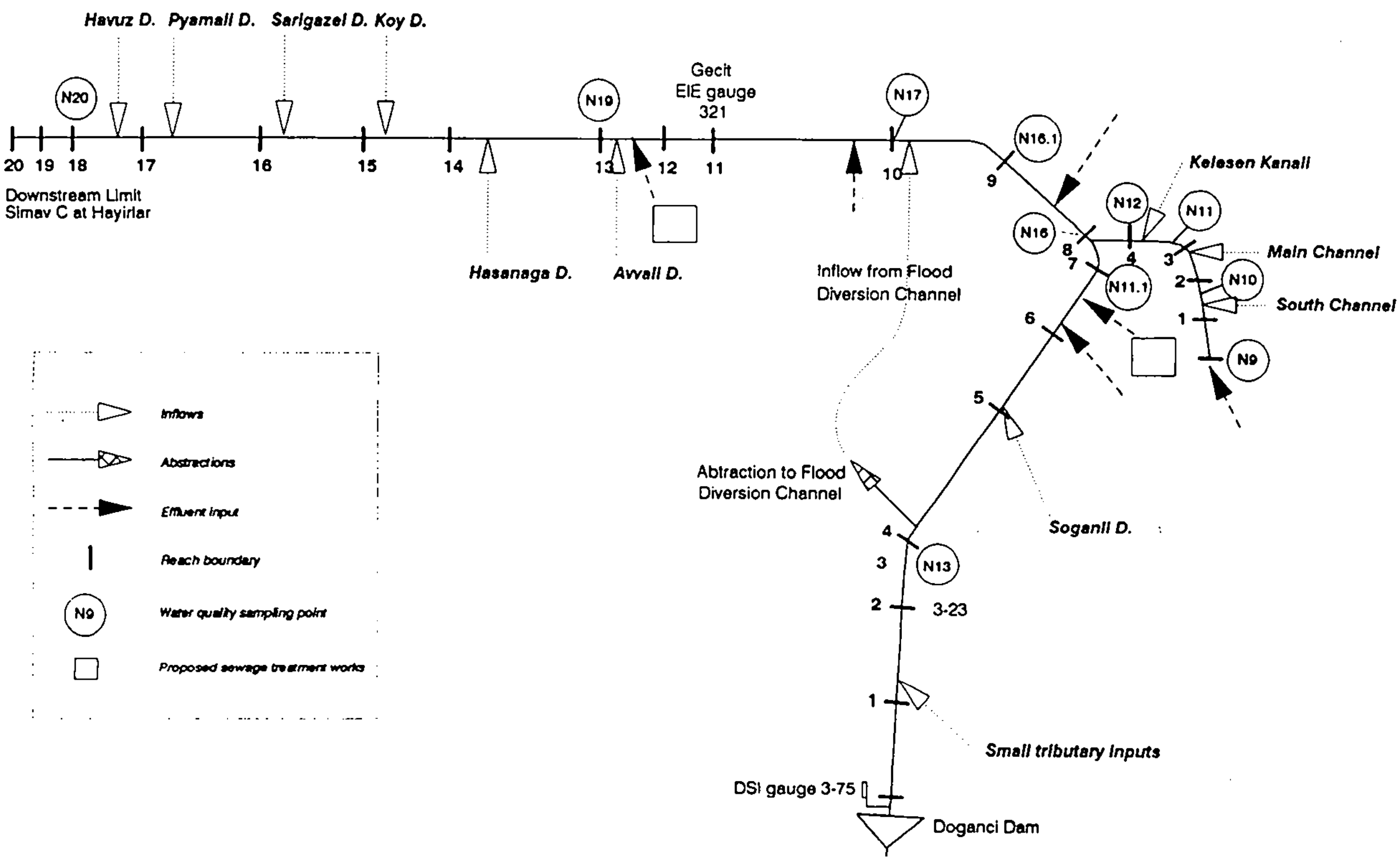


Figure 4.1.1

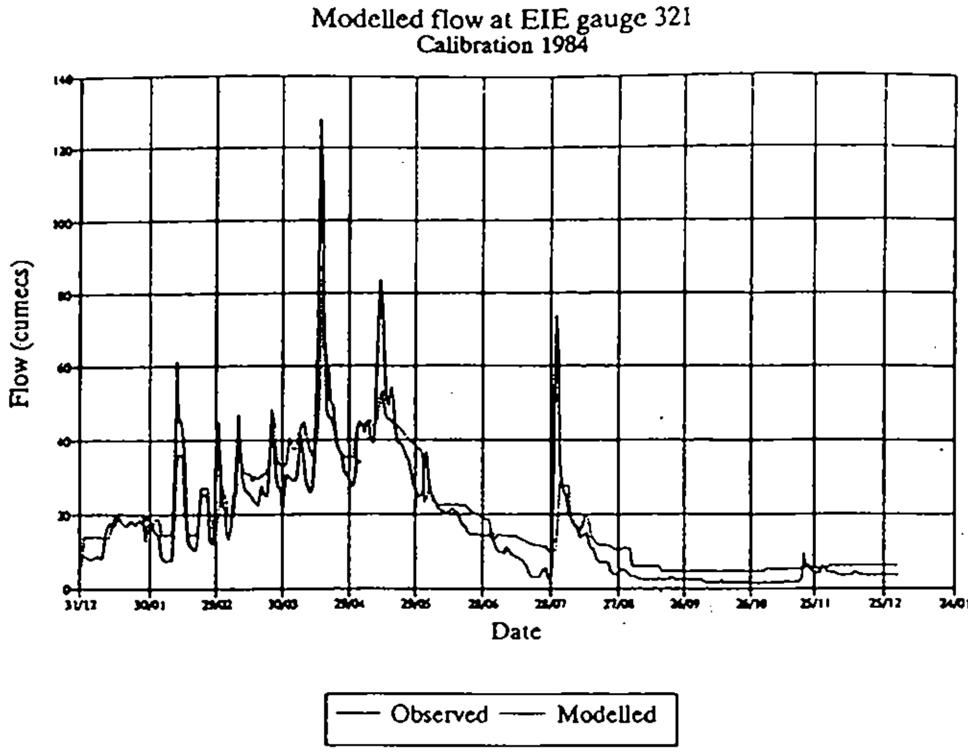


Figure 4.1.2

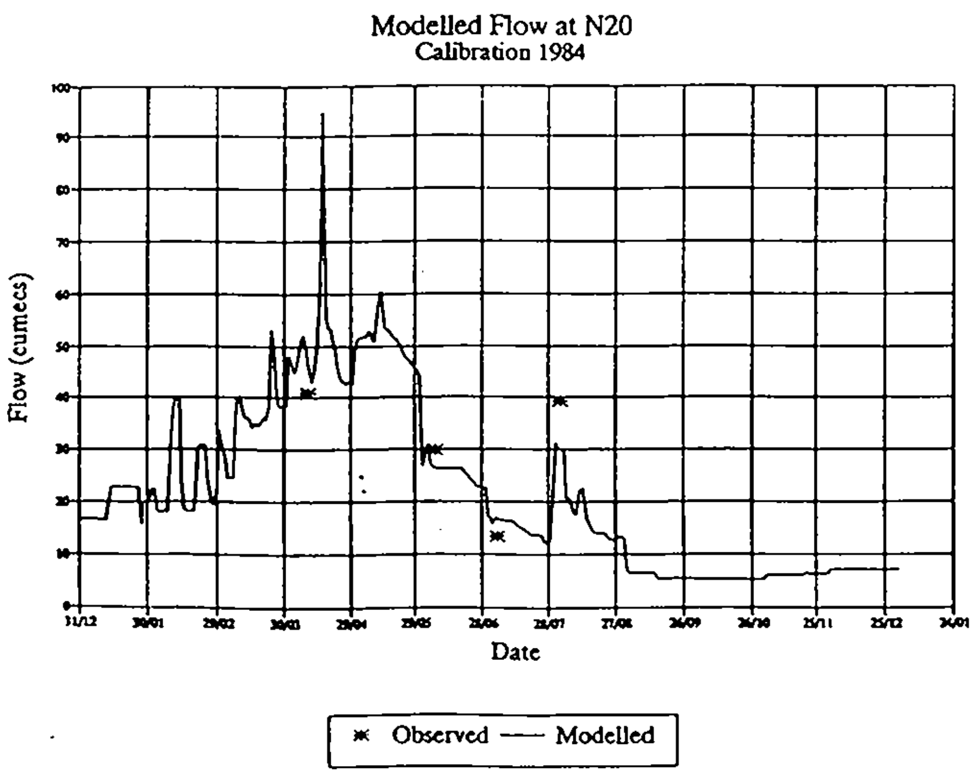


Figure 4.1.3

Table 4.1.1 Reaches used in QUASAR

Reach number	From	To	Length (km)	Cumulative Area (km^2)	Inflows/Outflows	Effluent	Water Quality
<u>Nilufer</u>							
0	Upstream of Doganci	Doganci dam		447			
1	Doganci dam	Dagyenci	4.4				N21
2	Dagyenci	DSI gauge 3-23	3.0		Small tributaries		N22
3	DSI gauge 3-23	DSI WQ sample N13	4.8				
4	N13	Flood diversion channel (FDC)	1.6				
5	FDC	Soganli D.	3.4		- FDC		
6	Soganli D.	Kucuk baliki	1.25		Soganli D.		N14
7	Kucuk baliki	DSI WQ sample N11.1	2.65			Effluent	N9
8	N11.1	DSI WQ sample N16	.38		Left bank channels		
9	N16	DSI WQ sample 16.1	4.2			Effluent	N9
10	N16.1	DSI sample N17	3.6		+ FDC	Proposed STW	N18
11	N17	Gecit EIE gauge 321	7.2	1290		Effluent	N9
12	Gecit	Haksoy	4.7				
13	Haksoy	DSI WQ sample N19	5.8		Avvali D.	Industrial STW	N18
14	N19	Getrice	7.4		Hasanaga D.		N1
15	Cekrice	Konakli	2.2		Koy D.		N1
16	Konakli	Yorukenicesi	7.9		Sarigazel D.		N1
17	Yorukenicesi	Cayonu	11.6		Pyamali D.		N1
18	Cayonu	DSI WQ sample N20	12.2		Havuz D.		N1
19	N20	Besi Dami	6.1				
20	Besi Bani	Confluence with Simavi C.	7.2				
		Total	101.6	1927			

DRAINAGE CHANNELS

1	DSI WQ sample N9	Upstream confluence of south channel	1.4		N9
2	S.Channel	DSI WQ sample N10	0.6	South channel	N11
3	N10	Downstream confluence main channel	1.1	Main channel	N11
4	Main channel	DSI WQ sample N12	0.9		
5	N12	Confluence with Nilufer	0.25		
		Total	4.25		

Table 4.2.1 Output from QUASAR; dry season, current conditions

Flow (m3/sec)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	0.9	1.9	0.0	0.3	3.6
3.23 (Nilufer)	1.3	2.1	0.1	0.7	5.2
N13 (Nilufer)	1.3	2.1	0.1	0.7	5.2
flood diversion channel (Nilufer)	1.3	2.1	0.1	0.7	5.2
Soganali D. (Nilufer)	1.3	2.1	0.1	0.7	5.2
Kucuk Balikli (Nilufer)	1.9	2.1	0.7	1.3	5.8
N11.1 (Nilufer)	3.1	2.1	1.7	2.5	7.1
N16 (Nilufer)	5.6	2.3	3.4	5.0	9.8
N16.1 (Nilufer)	6.3	2.3	4.2	5.8	10.5
N17 (Nilufer)	6.8	2.3	4.7	6.3	11.0
Gecit (Nilufer)	7.4	2.4	5.2	6.9	11.5
Haksoy (Nilufer)	7.4	2.4	5.2	6.9	11.5
N19 (Nilufer)	7.9	2.4	5.5	7.4	12.6
Cekrice (Nilufer)	8.5	2.4	6.0	8.0	13.3
Konakli (Nilufer)	8.8	2.4	6.3	8.3	13.5
Yorukyenicesi (Nilufer)	9.1	2.4	6.5	8.5	13.7
Cayonu (Nilufer)	9.3	2.4	6.8	8.7	13.9
N20 (Nilufer)	9.3	2.4	6.8	8.8	13.9
Besi Dami (Nilufer)	9.5	2.4	7.0	9.0	14.2
Confluence with Simav C. (Nilufer)	9.5	2.4	7.0	9.0	14.2

Chloride (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	9.5	4.4	4.3	8.6	17.0
3.23 (Nilufer)	8.5	3.0	4.8	8.0	14.0
N13 (Nilufer)	8.5	3.0	4.9	8.0	14.0
flood diversion channel (Nilufer)	8.5	3.0	4.9	8.0	14.0
Soganali D. (Nilufer)	8.5	3.0	4.9	8.0	14.0
Kucuk Balikli (Nilufer)	45.5	40.4	11.8	33.5	123.9
N11.1 (Nilufer)	49.0	22.2	22.8	45.7	89.7
N16 (Nilufer)	44.0	16.0	23.3	41.2	73.1
N16.1 (Nilufer)	45.9	14.5	24.9	44.1	71.8
N17 (Nilufer)	64.7	27.9	33.6	59.5	102.8
Gecit (Nilufer)	64.1	25.9	34.8	60.0	98.9
Haksoy (Nilufer)	64.1	25.9	34.8	60.0	98.9
N19 (Nilufer)	76.3	29.8	40.1	70.8	121.4
Cekrice (Nilufer)	71.6	26.7	39.5	66.8	113.4
Konakli (Nilufer)	69.8	25.8	38.8	65.5	111.5
Yorukyenicesi (Nilufer)	68.1	25.0	37.5	64.1	109.3
Cayonu (Nilufer)	66.9	24.3	37.1	63.0	107.1
N20 (Nilufer)	66.6	24.2	37.0	62.6	106.3
Besi Dami (Nilufer)	65.8	23.8	36.9	61.8	104.4
Confluence with Simav C. (Nilufer)	65.8	23.8	36.9	61.8	104.4

Table 4.2.1 (cont) Output from QUASAR: dry season, current conditions

Dissolved oxygen (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	6.4	3.2	0.0	7.3	10.4
3.23 (Nilufer)	6.5	3.0	0.0	7.4	10.1
N13 (Nilufer)	6.2	3.1	0.0	7.3	9.8
flood diversion channel (Nilufer)	5.9	3.1	0.0	7.0	9.6
Soganali D. (Nilufer)	5.8	3.1	0.0	6.9	9.5
Kucuk Balikli (Nilufer)	1.6	2.5	0.0	0.0	6.7
N11.1 (Nilufer)	0.4	1.3	0.0	0.0	3.3
N16 (Nilufer)	0.3	1.0	0.0	0.0	2.5
N16.1 (Nilufer)	0.1	0.5	0.0	0.0	0.0
N17 (Nilufer)	0.0	0.3	0.0	0.0	0.0
Gecit (Nilufer)	0.0	0.3	0.0	0.0	0.0
Haksoy (Nilufer)	0.0	0.1	0.0	0.0	0.0
N19 (Nilufer)	0.0	0.1	0.0	0.0	0.0
Cekrice (Nilufer)	0.0	0.1	0.0	0.0	0.0
Konakli (Nilufer)	0.0	0.1	0.0	0.0	0.0
Yorukyenicesi (Nilufer)	0.0	0.1	0.0	0.0	0.0
Cayonu (Nilufer)	0.0	0.1	0.0	0.0	0.0
N20 (Nilufer)	0.0	0.1	0.0	0.0	0.0
Besi Dami (Nilufer)	0.0	0.1	0.0	0.0	0.0
Confluence with Simav C. (Nilufer)	0.0	0.1	0.0	0.0	0.0

BOD (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	2.2	4.7	0.3	1.4	5.3
3.23 (Nilufer)	1.5	1.7	0.3	1.1	3.8
N13 (Nilufer)	1.2	1.6	0.1	0.8	3.3
flood diversion channel (Nilufer)	1.0	1.6	0.0	0.7	3.0
Soganali D. (Nilufer)	0.9	1.5	0.0	0.6	2.7
Kucuk Balikli (Nilufer)	69.7	46.1	13.9	59.3	158.0
N11.1 (Nilufer)	85.6	44.2	30.5	77.7	165.3
N16 (Nilufer)	70.4	29.7	32.4	66.2	125.3
N16.1 (Nilufer)	74.2	28.0	36.4	70.0	126.3
N17 (Nilufer)	81.0	27.2	43.5	77.7	131.1
Gecit (Nilufer)	80.7	25.2	45.4	77.4	125.3
Haksoy (Nilufer)	79.1	24.7	44.7	75.8	122.7
N19 (Nilufer)	82.8	24.2	48.0	80.9	126.5
Cekrice (Nilufer)	74.5	21.5	44.4	72.7	115.7
Konakli (Nilufer)	71.6	20.5	43.0	69.6	109.4
Yorukyenicesi (Nilufer)	67.4	19.2	41.1	65.8	101.9
Cayonu (Nilufer)	62.9	17.9	38.9	61.0	94.4
N20 (Nilufer)	59.6	16.9	36.9	57.7	88.8
Besi Dami (Nilufer)	57.3	16.2	35.5	55.6	85.1
Confluence with Simav C. (Nilufer)	55.7	15.7	34.5	54.0	82.7

Table 4.2.1 (cont) Output from QUASAR; dry season, current conditions

E. Coli	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	4473	59904	78	567	4458
3.23 (Nilufer)	1443	2819	161	738	4640
N13 (Nilufer)	1237	2644	101	609	4182
flood diversion channel (Nilufer)	1177	2598	75	573	4032
Soganali D. (Nilufer)	1142	2538	70	552	3888
Kucuk Balikli (Nilufer)	3858986	3779657	511798	2664209	11087072
N11.1 (Nilufer)	4928784	3370943	1244010	4009222	11326270
N16 (Nilufer)	3249419	1914364	1041103	2803046	6656779
N16.1 (Nilufer)	3734094	1956514	1475341	3330832	7428342
N17 (Nilufer)	3418543	1766178	1371336	3061025	6665382
Gecit (Nilufer)	3592419	1782411	1546578	3241339	6808082
Haksoy (Nilufer)	3521670	1744616	1516941	3173647	6666279
N19 (Nilufer)	3247895	1591078	1409718	2930320	6184168
Cekrice (Nilufer)	2908000	1408766	1298606	2613816	5613783
Konakli (Nilufer)	2789175	1344894	1251520	2513739	5353993
Yorukyenicesi (Nilufer)	2618108	1258473	1178522	2354300	4930126
Cayonu (Nilufer)	2443935	1173243	1107175	2201743	4608769
N20 (Nilufer)	2313220	1109166	1050849	2077779	4409682
Besi Dami (Nilufer)	2222966	1063749	1011078	1997362	4244702
Confluence with Simav C. (Nilufer)	2160956	1033528	982330	1943480	4113262

pH	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	8.3	0.3	7.8	8.3	8.9
3.23 (Nilufer)	8.1	0.3	7.7	8.1	8.5
N13 (Nilufer)	8.1	0.3	7.7	8.1	8.5
flood diversion channel (Nilufer)	8.1	0.3	7.7	8.1	8.5
Soganali D. (Nilufer)	8.1	0.3	7.7	8.1	8.5
Kucuk Balikli (Nilufer)	7.8	0.2	7.4	7.8	8.2
N11.1 (Nilufer)	7.8	0.2	7.5	7.8	8.1
N16 (Nilufer)	7.8	0.2	7.5	7.8	8.0
N16.1 (Nilufer)	7.8	0.1	7.5	7.8	8.0
N17 (Nilufer)	7.8	0.1	7.5	7.8	8.0
Gecit (Nilufer)	7.8	0.1	7.5	7.8	8.0
Haksoy (Nilufer)	7.8	0.1	7.5	7.8	8.0
N19 (Nilufer)	7.8	0.1	7.5	7.8	8.0
Cekrice (Nilufer)	7.8	0.1	7.6	7.8	8.0
Konakli (Nilufer)	7.8	0.1	7.6	7.8	8.0
Yorukyenicesi (Nilufer)	7.8	0.1	7.6	7.8	8.0
Cayonu (Nilufer)	7.8	0.1	7.6	7.8	8.0
N20 (Nilufer)	7.8	0.1	7.6	7.8	8.0
Besi Dami (Nilufer)	7.8	0.1	7.6	7.8	8.0
Confluence with Simav C. (Nilufer)	7.8	0.1	7.6	7.8	8.0

TABLE 4.2.2 Output from QUASAR; dry season, current conditions

Flow (m3/sec)	Mean	sd	5%	50%	95%
Upstream of confluence of S. Channel	0.5	0.2	0.3	0.5	0.9
Upstream N10	0.8	0.3	0.4	0.8	1.4
Upstream of confluence of Main Channel	1.2	0.4	0.7	1.2	2.0
Downstream of confluence of Main Channel	2.4	1.0	1.3	2.3	4.2
Confluence with Nilufer	2.5	1.0	1.3	2.3	4.2

Chloride (mg/l)	Mean	sd	5%	50%	95%
Upstream of confluence of S. Channel	59.2	22.9	30.3	55.1	101.8
Upstream N10	44.9	18.3	22.6	40.8	78.7
Upstream of confluence of Main Channel	34.7	13.6	18.1	31.8	61.5
Downstream of confluence of Main Channel	39.5	21.8	18.1	33.8	76.3
Confluence with Nilufer	39.5	21.8	18.1	33.7	76.3

Dissolved oxygen (mg/l)	Mean	sd	5%	50%	95%
Upstream of confluence of S. Channel	0.2	1.1	0.0	0.0	1.1
Upstream N10	0.5	1.3	0.0	0.0	3.5
Upstream of confluence of Main Channel	0.5	1.2	0.0	0.0	3.4
Downstream of confluence of Main Channel	0.5	1.3	0.0	0.0	3.3
Confluence with Nilufer	0.4	1.1	0.0	0.0	2.8

BOD (mg/l)	Mean	sd	5%	50%	95%
Upstream of confluence of S. Channel	109.8	54.4	44.6	97.9	214.8
Upstream N10	76.6	41.4	26.6	68.6	147.3
Upstream of confluence of Main Channel	52.6	30.4	17.9	46.1	109.4
Downstream of confluence of Main Channel	57.0	33.7	21.3	48.6	125.3
Confluence with Nilufer	56.9	33.7	21.0	48.7	125.0

E. Coli	Mean	sd	5%	50%	95%
Upstream of confluence of S. Channel	6991313	6975560	1201918	4815998	21114042
Upstream N10	4621985	4662481	702969	3200907	14063062
Upstream of confluence of Main Channel	3030463	3149492	434712	1988255	9127983
Downstream of confluence of Main Channel	1631721	1702786	214145	1018015	5106919
Confluence with Nilufer	1625181	1698791	213608	1015079	5094080

pH	Mean	sd	5%	50%	95%
Upstream of confluence of S. Channel	7.8	0.2	7.4	7.8	8.2
Upstream N10	7.8	0.2	7.4	7.8	8.2
Upstream of confluence of Main Channel	7.8	0.2	7.5	7.8	8.2
Downstream of confluence of Main Channel	7.8	0.2	7.4	7.8	8.2
Confluence with Nilufer	7.8	0.2	7.4	7.8	8.2

Table 4.2.3 Output from QUASAR; dry season, year 2000, anaerobic ponds

Flow (m3/sec)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	1.0	2.4	0.0	0.3	3.7
3.23 (Nilufer)	1.4	2.6	0.1	0.6	4.6
N13 (Nilufer)	1.4	2.6	0.1	0.7	4.6
flood diversion channel (Nilufer)	1.4	2.6	0.1	0.7	4.6
Soganali D. (Nilufer)	1.4	2.6	0.1	0.7	4.6
Kucuk Balikli (Nilufer)	1.6	2.6	0.3	0.9	4.9
N11.1 (Nilufer)	3.2	2.6	1.9	2.4	6.4
N16 (Nilufer)	5.7	2.7	3.7	4.9	9.6
N16.1 (Nilufer)	6.4	2.7	4.3	5.6	10.5
N17 (Nilufer)	6.7	2.7	4.6	6.0	10.9
Gecit (Nilufer)	7.1	2.7	5.0	6.4	11.4
Haksoy (Nilufer)	7.1	2.7	5.0	6.4	11.4
N19 (Nilufer)	8.0	2.7	5.9	7.3	12.2
Cekrice (Nilufer)	8.6	2.8	6.4	7.9	12.9
Konakli (Nilufer)	8.9	2.8	6.7	8.1	13.2
Yorukyenicesi (Nilufer)	9.1	2.8	6.9	8.4	13.5
Cayonu (Nilufer)	9.3	2.8	7.1	8.6	13.7
N20 (Nilufer)	9.4	2.8	7.2	8.6	13.7
Besi Dami (Nilufer)	9.5	2.8	7.3	8.8	13.8
Confluence with Simav C. (Nilufer)	9.5	2.8	7.3	8.8	13.8

Chloride (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	9.3	4.3	4.5	8.5	16.7
3.23 (Nilufer)	8.4	2.8	4.9	7.8	13.3
N13 (Nilufer)	8.4	2.8	4.9	7.8	13.3
flood diversion channel (Nilufer)	8.4	2.8	4.9	7.8	13.3
Soganali D. (Nilufer)	8.4	2.8	4.9	7.8	13.3
Kucuk Balikli (Nilufer)	8.1	2.3	5.4	7.6	12.0
N11.1 (Nilufer)	30.5	15.7	11.7	26.4	61.5
N16 (Nilufer)	34.5	15.0	16.5	31.7	61.5
N16.1 (Nilufer)	37.4	13.7	19.6	35.0	61.8
N17 (Nilufer)	36.7	12.9	20.2	34.5	60.0
Gecit (Nilufer)	35.5	12.3	19.6	33.3	57.4
Haksoy (Nilufer)	35.5	12.3	19.6	33.3	57.4
N19 (Nilufer)	48.8	19.7	25.8	45.3	86.7
Cekrice (Nilufer)	46.4	18.1	24.6	43.1	80.7
Konakli (Nilufer)	45.5	17.5	24.3	42.3	78.9
Yorukyenicesi (Nilufer)	44.5	16.9	24.1	41.6	77.2
Cayonu (Nilufer)	43.8	16.5	24.1	40.9	75.5
N20 (Nilufer)	43.6	16.4	24.0	40.7	75.3
Besi Dami (Nilufer)	43.2	16.1	23.9	40.2	73.3
Confluence with Simav C. (Nilufer)	43.2	16.1	23.9	40.2	73.3

Table 4.2.3 (cont) Output from QUASAR; dry season, year 2000, anaerobic ponds

Dissolved oxygen (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	7.4	3.0	0.1	8.2	10.7
3.23 (Nilufer)	7.5	2.7	0.3	8.2	10.5
N13 (Nilufer)	7.4	2.8	0.1	8.3	10.2
flood diversion channel (Nilufer)	7.2	2.9	0.0	8.2	10.1
Soganali D. (Nilufer)	7.2	2.9	0.1	8.2	10.1
Kucuk Balikli (Nilufer)	7.7	2.3	2.2	8.4	10.0
N11.1 (Nilufer)	1.9	2.1	0.0	1.2	6.2
N16 (Nilufer)	3.0	1.8	0.4	2.7	6.3
N16.1 (Nilufer)	2.0	1.8	0.0	1.7	5.5
N17 (Nilufer)	1.5	1.7	0.0	1.1	5.2
Gecit (Nilufer)	1.2	1.6	0.0	0.5	4.6
Haksoy (Nilufer)	0.9	1.5	0.0	0.0	4.2
N19 (Nilufer)	0.8	1.4	0.0	0.0	3.5
Cekrice (Nilufer)	0.9	1.4	0.0	0.3	3.8
Konakli (Nilufer)	1.1	1.4	0.0	0.5	3.9
Yorukyenicesi (Nilufer)	1.1	1.4	0.0	0.5	3.8
Cayonu (Nilufer)	1.2	1.5	0.0	0.6	3.9
N20 (Nilufer)	1.3	1.5	0.0	0.8	4.0
Besi Dami (Nilufer)	1.4	1.5	0.0	1.0	4.2
Confluence with Simav C. (Nilufer)	1.5	1.6	0.0	1.2	4.3

BOD (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	2.2	3.9	0.3	1.3	5.9
3.23 (Nilufer)	1.6	1.3	0.4	1.2	3.7
N13 (Nilufer)	1.3	1.3	0.2	1.0	3.2
flood diversion channel (Nilufer)	1.2	1.3	0.2	0.9	3.1
Soganali D. (Nilufer)	1.2	1.2	0.1	0.9	2.9
Kucuk Balikli (Nilufer)	1.4	1.0	0.5	1.1	2.9
N11.1 (Nilufer)	105.7	32.4	40.8	112.1	146.0
N16 (Nilufer)	81.5	25.2	43.8	80.6	121.8
N16.1 (Nilufer)	82.2	23.7	45.0	81.5	120.5
N17 (Nilufer)	77.3	21.9	43.8	76.1	111.1
Gecit (Nilufer)	69.6	19.7	39.9	67.6	100.3
Haksoy (Nilufer)	67.8	19.3	38.6	65.7	98.1
N19 (Nilufer)	71.3	17.9	43.3	69.8	98.3
Cekrice (Nilufer)	63.3	15.8	39.8	62.3	87.4
Konakli (Nilufer)	60.6	15.0	38.8	59.5	84.1
Yorukyenicesi (Nilufer)	56.1	13.9	36.0	55.2	78.5
Cayonu (Nilufer)	51.4	13.0	32.9	50.3	72.8
N20 (Nilufer)	47.7	12.5	30.4	46.4	68.4
Besi Dami (Nilufer)	45.3	12.0	28.8	43.9	64.6
Confluence with Simav C. (Nilufer)	43.5	11.7	27.5	41.9	62.8

Table 4.2.3 (cont) Output from QUASAR; dry season, year 2000, anaerobic ponds

E. Coli	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	9573	153158	83	545	6330
3.23 (Nilufer)	1622	2416	161	827	4958
N13 (Nilufer)	1557	2342	153	795	4950
flood diversion channel (Nilufer)	1536	2319	148	785	4950
Soganali D. (Nilufer)	1527	2307	147	782	4941
Kucuk Balikli (Nilufer)	1649	1965	270	1028	4887
N11.1 (Nilufer)	3198965	4443485	315286	1999905	9926845
N16 (Nilufer)	2393198	2449410	501054	1801347	6150427
N16.1 (Nilufer)	3085585	2543072	846381	2466913	7251103
N17 (Nilufer)	2959732	2377513	848355	2370214	6808842
Gecit (Nilufer)	2765553	2196645	793554	2227027	6478295
Haksoy (Nilufer)	2755711	2188734	790696	2218631	6454809
N19 (Nilufer)	2489283	1905290	760900	2052965	5791586
Cekrice (Nilufer)	2288181	1761351	730685	1892786	5152690
Konakli (Nilufer)	2213949	1696230	721656	1827250	5005320
Yorukyenicesi (Nilufer)	2133409	1633684	683844	1766537	4832638
Cayonu (Nilufer)	2069823	1586238	649086	1721309	4682560
N20 (Nilufer)	2039333	1562803	638712	1693547	4622532
Besi Dami (Nilufer)	1999188	1527745	633769	1661439	4480499
Confluence with Simav C. (Nilufer)	1989597	1520283	631547	1653891	4459006

pH	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	8.3	0.3	7.8	8.3	8.9
3.23 (Nilufer)	8.1	0.3	7.7	8.1	8.6
N13 (Nilufer)	8.1	0.3	7.7	8.1	8.6
flood diversion channel (Nilufer)	8.1	0.3	7.7	8.1	8.6
Soganali D. (Nilufer)	8.1	0.3	7.7	8.1	8.6
Kucuk Balikli (Nilufer)	8.0	0.2	7.7	8.0	8.4
N11.1 (Nilufer)	6.7	0.3	6.3	6.7	7.3
N16 (Nilufer)	7.0	0.3	6.6	7.0	7.4
N16.1 (Nilufer)	7.0	0.2	6.6	7.0	7.4
N17 (Nilufer)	7.0	0.2	6.7	7.1	7.4
Gecit (Nilufer)	6.5	0.8	4.8	6.8	7.4
Haksoy (Nilufer)	6.5	0.8	4.8	6.8	7.4
N19 (Nilufer)	6.5	0.8	4.9	6.8	7.2
Cekrice (Nilufer)	6.5	0.8	4.9	6.8	7.3
Konakli (Nilufer)	6.5	0.8	4.9	6.8	7.3
Yorukyenicesi (Nilufer)	6.5	0.8	4.9	6.8	7.3
Cayonu (Nilufer)	6.5	0.8	4.9	6.9	7.3
N20 (Nilufer)	6.5	0.8	4.9	6.9	7.3
Besi Dami (Nilufer)	6.6	0.8	4.9	6.9	7.3
Confluence with Simav C. (Nilufer)	6.6	0.8	4.9	6.9	7.3

Table 4.2.4 Output from QUASAR; dry season, year 2000, activated sludge process

Flow (m3/sec)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	0.9	2.3	0.0	0.3	3.5
3.23 (Nilufer)	1.2	2.3	0.1	0.7	3.6
N13 (Nilufer)	1.2	2.3	0.1	0.7	3.6
flood diversion channel (Nilufer)	1.2	2.3	0.1	0.7	3.6
Soganali D. (Nilufer)	1.2	2.3	0.1	0.7	3.6
Kucuk Balikli (Nilufer)	1.4	2.3	0.3	0.9	3.8
N11.1 (Nilufer)	3.0	2.3	1.9	2.4	5.3
N16 (Nilufer)	5.5	2.6	3.4	5.0	8.8
N16.1 (Nilufer)	6.2	2.6	4.1	5.7	9.5
N17 (Nilufer)	6.6	2.6	4.4	6.1	9.9
Gecit (Nilufer)	6.9	2.6	4.7	6.5	10.4
Haksoy (Nilufer)	6.9	2.6	4.7	6.5	10.4
N19 (Nilufer)	7.8	2.6	5.5	7.3	11.2
Cekrice (Nilufer)	8.4	2.6	6.1	8.0	11.8
Konakli (Nilufer)	8.7	2.7	6.3	8.2	12.1
Yorukyenicesi (Nilufer)	9.0	2.7	6.6	8.5	12.3
Cayonu (Nilufer)	9.2	2.6	6.8	8.7	12.4
N20 (Nilufer)	9.2	2.6	6.9	8.8	12.5
Besi Dami (Nilufer)	9.4	2.6	7.0	8.9	12.7
Confluence with Simav C. (Nilufer)	9.4	2.6	7.0	8.9	12.7

Chloride (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	9.5	4.3	4.2	8.7	17.0
3.23 (Nilufer)	8.3	2.7	4.6	7.9	13.1
N13 (Nilufer)	8.3	2.7	4.7	7.9	13.1
flood diversion channel (Nilufer)	8.3	2.7	4.7	7.9	13.1
Soganali D. (Nilufer)	8.3	2.7	4.7	7.9	13.1
Kucuk Balikli (Nilufer)	8.0	2.2	5.1	7.7	12.1
N11.1 (Nilufer)	29.4	15.7	11.9	26.0	61.4
N16 (Nilufer)	33.6	12.5	17.2	31.3	56.4
N16.1 (Nilufer)	36.7	11.5	21.0	35.2	57.3
N17 (Nilufer)	35.9	11.0	21.2	34.4	56.5
Gecit (Nilufer)	34.7	10.4	21.0	33.2	53.6
Haksoy (Nilufer)	34.7	10.4	21.0	33.2	53.6
N19 (Nilufer)	47.4	18.1	27.0	43.3	79.6
Cekrice (Nilufer)	44.9	16.4	26.2	41.5	73.1
Konakli (Nilufer)	44.0	15.8	25.9	40.5	71.4
Yorukyenicesi (Nilufer)	43.1	15.3	25.7	39.8	69.1
Cayonu (Nilufer)	42.5	14.9	25.4	39.3	67.7
N20 (Nilufer)	42.3	14.8	25.3	39.2	67.0
Besi Dami (Nilufer)	41.9	14.5	25.2	38.7	65.9
Confluence with Simav C. (Nilufer)	41.9	14.5	25.2	38.7	65.9

Table 4.2.4 (cont) Output from QUASAR; dry season, year 2000, activated sludge process

Dissolved oxygen (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	7.6	2.9	0.2	8.2	10.7
3.23 (Nilufer)	7.8	2.5	0.8	8.3	11.0
N13 (Nilufer)	7.7	2.6	0.4	8.4	10.5
flood diversion channel (Nilufer)	7.5	2.7	0.2	8.3	10.2
Soganali D. (Nilufer)	7.5	2.7	0.4	8.3	10.2
Kucuk Balikli (Nilufer)	8.0	2.1	2.8	8.5	10.2
N11.1 (Nilufer)	3.9	1.6	1.6	3.8	6.7
N16 (Nilufer)	3.9	1.6	1.5	3.8	6.6
N16.1 (Nilufer)	3.0	1.6	0.4	2.9	5.8
N17 (Nilufer)	2.6	1.7	0.0	2.5	5.4
Gecit (Nilufer)	2.2	1.6	0.0	2.2	5.1
Haksoy (Nilufer)	1.9	1.6	0.0	1.7	4.8
N19 (Nilufer)	1.8	1.5	0.0	1.6	4.5
Cekrice (Nilufer)	2.2	1.5	0.0	2.2	4.7
Konakli (Nilufer)	2.4	1.5	0.0	2.4	4.9
Yorukyenicesi (Nilufer)	2.6	1.5	0.0	2.6	5.0
Cayonu (Nilufer)	2.7	1.5	0.0	2.8	5.0
N20 (Nilufer)	2.9	1.6	0.0	3.0	5.1
Besi Dami (Nilufer)	3.1	1.6	0.0	3.2	5.3
Confluence with Simav C. (Nilufer)	3.2	1.6	0.0	3.3	5.3

BOD (mg/l)	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	2.2	3.2	0.4	1.4	6.3
3.23 (Nilufer)	1.7	1.6	0.4	1.3	4.2
N13 (Nilufer)	1.4	1.5	0.2	1.1	3.7
flood diversion channel (Nilufer)	1.3	1.5	0.1	1.0	3.6
Soganali D. (Nilufer)	1.3	1.4	0.1	0.9	3.4
Kucuk Balikli (Nilufer)	1.5	1.2	0.5	1.3	3.3
N11.1 (Nilufer)	12.5	3.1	6.7	13.0	16.3
N16 (Nilufer)	33.5	19.5	14.5	28.8	68.0
N16.1 (Nilufer)	42.6	19.1	21.1	39.0	78.1
N17 (Nilufer)	40.7	17.8	20.4	38.1	74.7
Gecit (Nilufer)	36.7	16.2	18.1	34.5	67.2
Haksoy (Nilufer)	35.5	15.8	17.8	33.3	65.5
N19 (Nilufer)	32.7	13.8	17.4	30.7	58.7
Cekrice (Nilufer)	29.0	12.3	15.8	27.0	51.1
Konakli (Nilufer)	27.8	11.9	15.2	25.9	49.5
Yorukyenicesi (Nilufer)	25.7	11.1	14.1	23.7	46.0
Cayonu (Nilufer)	23.4	10.2	12.8	21.6	41.9
N20 (Nilufer)	21.5	9.5	11.6	19.7	38.3
Besi Dami (Nilufer)	20.4	9.1	11.0	18.7	35.6
Confluence with Simav C. (Nilufer)	19.5	8.7	10.5	17.8	33.9

Table 4.2.4 (cont) Output from QUASAR; dry season, year 2000, activated sludge process

E. Coli	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	6150	76087	75	636	4312
3.23 (Nilufer)	1608	4004	210	936	4152
N13 (Nilufer)	1526	3967	203	875	4129
flood diversion channel (Nilufer)	1501	3957	202	859	4054
Soganali D. (Nilufer)	1492	3946	201	855	4033
Kucuk Balikli (Nilufer)	1677	3805	303	1079	4208
N11.1 (Nilufer)	2769062	3619893	381434	1807494	7173689
N16 (Nilufer)	2226342	2188810	535474	1654077	5469673
N16.1 (Nilufer)	2852108	2184432	821661	2376627	6665864
N17 (Nilufer)	2740902	2040125	808487	2290648	6318371
Gecit (Nilufer)	2570159	1910660	763247	2162607	5622990
Haksoy (Nilufer)	2560688	1903677	760502	2149407	5604392
N19 (Nilufer)	2307599	1649237	711354	1939088	5055899
Cekrice (Nilufer)	2113816	1510842	672080	1774352	4599272
Konakli (Nilufer)	2041659	1451486	652817	1719096	4388154
Yorukyenicesi (Nilufer)	1965884	1398693	624826	1650084	4210718
Cayonu (Nilufer)	1905387	1354046	610712	1603444	4074327
N20 (Nilufer)	1876320	1332312	602463	1574818	4005925
Besi Dami (Nilufer)	1838941	1304161	593539	1541962	3936544
Confluence with Simav C. (Nilufer)	1830073	1297750	590734	1534679	3918280

pH	Mean	sd	5%	50%	95%
Dagyence (Nilufer)	8.3	0.3	7.8	8.3	8.9
3.23 (Nilufer)	8.1	0.3	7.7	8.1	8.6
N13 (Nilufer)	8.1	0.3	7.7	8.1	8.6
flood diversion channel (Nilufer)	8.1	0.3	7.7	8.1	8.6
Soganali D. (Nilufer)	8.1	0.3	7.7	8.1	8.6
Kucuk Balikli (Nilufer)	8.1	0.2	7.7	8.1	8.4
N11.1 (Nilufer)	7.2	0.2	7.1	7.2	7.5
N16 (Nilufer)	7.4	0.1	7.2	7.4	7.6
N16.1 (Nilufer)	7.4	0.1	7.3	7.4	7.6
N17 (Nilufer)	7.4	0.1	7.3	7.4	7.6
Gecit (Nilufer)	6.5	1.1	4.4	7.1	7.5
Haksoy (Nilufer)	6.5	1.1	4.4	7.1	7.5
N19 (Nilufer)	6.5	1.1	4.4	7.1	7.5
Cekrice (Nilufer)	6.6	1.1	4.4	7.2	7.5
Konakli (Nilufer)	6.6	1.1	4.5	7.2	7.5
Yorukyenicesi (Nilufer)	6.6	1.1	4.5	7.2	7.5
Cayonu (Nilufer)	6.6	1.1	4.5	7.2	7.6
N20 (Nilufer)	6.6	1.1	4.5	7.2	7.6
Besi Dami (Nilufer)	6.6	1.1	4.5	7.2	7.6
Confluence with Simav C. (Nilufer)	6.6	1.1	4.5	7.2	7.6

5 REQUIREMENTS FOR ADDITIONAL WORK

The model results presented here are based on a number of assumptions about the discharge rates and quality of the various tributary inflows and direct and indirect discharges. The assumptions have been necessary because of the lack of detailed data. Nevertheless QUASAR has been able to demonstrate how the implementation of sewage treatment works improves river water quality.

Routine monitoring of flows and water quality on the main watercourses in and around Bursa would provide better information on which to base future planning. It would be useful to install QUASAR locally, together with an associated water quality database, so that the performance of the surface water system could be monitored in terms of water quality and pollution. It would also be possible to use QUASAR locally to model the effects of any pollution accident.

Natural
Environment
Research
Council