

65449

**SIMULATION OF WATER QUALITY
ALONG RIVER COURSES
A CASE STUDY - GEDİZ RIVER BASIN**

**A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of
Dokuz Eylül University
In Partial Fulfillment of the Requirements for
the Master's Degree in Environmental Engineering,
Environmental Technology Program**

**by
Filiz BARBAROS**

**January, 1997
İZMİR**

M.Sc. THESIS EXAMINATION RESULT FORM

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as thesis for the degree of Master of Science.



Prof. Dr. Necdet Alpaslan
(Advisor)



Prof. Dr. Nilgün Harmancioğlu
(Committee Member)

Prof. Dr. Yüksel K. Bircay
(Committee Member)



Approved for the
Graduate School of Natural and Applied Sciences



Prof. Dr. Macit Toksoy
Director
Graduate School of Natural and Applied Sciences

ACKNOWLEDGMENT

In recent years, water resources problems and the required solutions have become highly complex such that it is now difficult both to identify among the numerous causes of pollution and to select the best management strategy. Recent advances in the computer technology have provided significant facilities in handling these problems so that most mathematical models have now become computer-based simulation models. With such models, it is possible to investigate large numbers of variables, processes and alternative management decisions. Furthermore, once a computer-based simulation is developed, management scenarios can be developed to infer on consequences of decisions made.

The study presented intends to demonstrate the application of such a simulation model in identifying water quality variations along river courses. The model selected is QUAL2E, which is a simulation package developed by EPA in the US and which has found a wide area of usage in many countries. In the current study, the characteristics and capabilities of the model are investigated, and an application is presented on the Gediz river basin.

The author is supported by a scholarship provided by TUBITAK-BAYG throughout her graduate studies which led to the realization of this thesis. This support is gratefully acknowledged.

The author is grateful to Prof. Dr. Necdet ALPASLAN, the advisor of the M. Sc. Thesis for his support; to Prof. Dr. Nilgün HARMANCIOĞLU for her kind contributions and efforts on this study; to Dr. Sevinç ÖZKUL for her support at every stage of the thesis, to Res. Assist. Okan FISTIKOĞLU (M. Sc.) for his support in computer applications; and finally to her family for their endless support.

Filiz BARBAROS
Env. Eng.
January 1997

ABSTRACT

The identification of water quality characteristics in space and time dimensions is essential for the development of efficient basin management policies. To this end, computer based simulation models have found a wide area of application as effective management tools. Simulation models can be used to develop numerical results about water quantity and quality for the decision making process. QUAL2E - Water Quality Model, which has been used for management purposes in several developed countries is selected for this study.

QUAL2E - Water Quality Model simulates water quality in space and time dimensions, helps to estimate the levels of pollution caused by polluting sources, and aids in the planning of appropriate monitoring programs to monitor the quality of surface waters. The uncertainty analysis component of the model also provides effective possibilities for risk analyses as an essential step for management.

In this study, the model is applied to the case of the Gediz river basin where the quality of surface waters has significantly degraded within the recent years. Due to limitations in data availability, water quality observations of only 6 monitoring stations operated in 1983 could be used in the study. If the model can be run with an updated data set, the results can be expected to provide a scientific basis for planners and managers of the basin towards better practices of water quality management.

ÖZET

Etkili bir havza yönetiminin geliştirilmesinde, su kalitesi parametrelerinin zamana ve yere göre tanımlanabilmesi zorunludur. Bu yüzden, bilgisayar destekli simülasyon (benzeşim) modelleri etkili yönetim araçları olarak geniş bir uygulama alanı bulmuştur. Simülasyon modelleri karar verme aşamasında, yüzeysel sulardaki akım ve kalitenin tanımı için sayısal değerler elde edilmesinde kullanılmaktadır. Birçok gelişmiş ülkede yönetim çalışmalarında yaygın olarak kullanılan QUAL2E - Su kalitesi modeli, sunulan çalışmada incelenmiş ve uygulanmıştır. QUAL2E - Su kalitesi modeli, su kalitesini zaman ve alan boyutlarında modelleyen, kirlilik kaynaklarınca oluşturulan kirliliğin boyutlarını belirlemede ve kirlетici kaynakları izlemek üzere, uygun bir ölçüm programının planlanmasına yardımcı olan bir bilgisayar program paketidir.

Sunulan çalışmada, önce QUAL2E modeli tanıtılarak modelin girdileri, çalışma prensibi ve ilgili özellikleri açıklanmıştır. Daha sonra model örnek olarak seçilen Gediz havzasının su kalitesinin benzeşimi için uygulanmıştır. Örnek olarak Gediz havzasının seçilmesinin en önemli nedeni, akarsuyun son yıllarda önemli ölçüde kirlenmiş ve kirlenmekte olmasıdır. Bu özelliği ile de birçok kamu ve özel kuruluşların ilgisini çekmektedir. Sunulan çalışma, bugüne kadar yapılan ve yapılmakta olan faaliyetlere katkıda bulunacak, havza yönetiminde karar veren kuruluşlara yönetim için önemli bir araç sağlanmış olacaktır.

CONTENTS

	Page
Contents.....	IV
List of Tables.....	VIII
List of Figures.....	XI

Chapter One

INTRODUCTION

1. INTRODUCTION	1
-----------------------	---

Chapter Two

THE USE OF MATHEMATICAL MODELS IN ENVIRONMENTAL MANAGEMENT

2. THE USE OF MATHEMATICAL MODELS IN ENVIRONMENTAL MANAGEMENT.....	4
2.1 GENERAL.....	4
2.2 MODELS.....	6
2.2.1 BASICS OF MATHEMATICAL MODELING.....	8
2.3 WATER QUALITY MODELING.....	11
2.4 TYPES OF WATER QUALITY MODELS.....	13

Chapter Three

DESCRIPTION OF THE QUAL2E MODEL

	Page
3. DESCRIPTION OF THE QUAL2E MODEL.....	17
3.1 GENERAL.....	17
3.2 THEORETICAL BACKGROUND OF QUAL2E.....	20
3.2.1 Mass Transport.....	20
3.2.2 Longitudinal Dispersion.....	23
3.2.3 Flow Augmentation.....	24
3.2.4 Constituent Reactions and Interrelationships.....	24
3.2.4.1 General.....	24
3.2.4.2 Phytoplanktonic Algae.....	25
3.2.4.3 Nitrogen Cycle.....	26
3.2.4.4 Phosphorus Cycle.....	27
3.2.4.5 Carbonaceous BOD.....	28
3.2.4.6 Dissolved Oxygen.....	29
3.2.4.7 Atmospheric Reaeration Coefficient Estimation.....	30
3.2.4.8 Dam Reaeration.....	32
3.2.4.9 Coliforms.....	32
3.2.4.10 Arbitrary Nonconservative Constituent.....	32
3.2.4.11 Temperature.....	33
3.3 DATA REQUIREMENTS.....	34
3.4 OUTPUT FILES.....	36
3.5 PROGRAM MODULES.....	39
3.5.1 AQUAL2 Module.....	39
3.5.2 QUAL2E Module.....	39
3.5.3 QUAL2EU Module.....	39
3.5.4 Q2PLOT Module.....	41
3.6 DATA LOADING.....	41
3.6.1 Uncertainty Data Loading.....	55
3.7 MODEL LIMITATIONS AND DEFAULT VALUES.....	56
3.8 BASIN IDENTIFICATION.....	57

Chapter Four

SELECTED RIVER BASIN

	Page
4. SELECTED RIVER BASIN.....	59
4.1 INTRODUCTION TO THE BASIN.....	59
4.1.1 Geology.....	60
4.1.2 Climate.....	60
4.1.3 Population.....	60
4.1.4 Water and Land Resources.....	61
4.1.4.1 Water Resources.....	61
4.1.4.2 Land Sources.....	63
4.1.5 Economy.....	63
4.2 WATER POTENTIAL (QUANTITY) OF THE GEDIZ RIVER BASIN.....	64
4.2.1 The Main River.....	64
4.2.2 Tributaries of the Gediz River.....	64
4.2.3 Streamflow Observations.....	65
4.3 WATER QUALITY OF THE GEDIZ RIVER BASIN.....	67
4.3.1 The Water Quality Observations.....	67
4.3.2 Current Status of Water Quality in the Basin.....	68

Chapter Five

CASE STUDY

5. CASE STUDY.....	71
5.1 GENERAL.....	71
5.2 PREPARATION OF THE INPUT DATA.....	72
5.3 APPLICATION OF THE MODEL.....	89
5.3.1 General.....	89
5.3.2 Model Run with Annual Values.....	89
5.3.3 Model Run with Seasonal Values of Water Quality Variables.....	97

Chapter Six

CONCLUSIONS

Page

6. CONCLUSIONS.....	112
---------------------	-----

REFERENCES

REFERENCES.....	115
-----------------	-----

APPENDICES

APPENDIX A: GLOBAL KINETICS PARAMETERS AND TEMPERATURE CORRECTION FACTORS LITERATURE REVIEW.....	A-1
APPENDIX B: MODEL LIMITATIONS AND DEFAULT VALUES.....	B-1
APPENDIX C: STREAMFLOW GAGING STATIONS DATA SET.....	C-1
APPENDIX D: WATER QUALITY OBSERVATION STATIONS DATA SETS.....	D-1
APPENDIX E: WATER QUALITY CLASSIFICATION FOR SURFACE WATERS.....	E-1
APPENDIX F: METEOROLOGICAL DATA SETS OF DMI (STATE METEOROLOGICAL WORKS).....	F-1

LIST OF TABLES

	Page
TABLE 2.1 MATHEMATICAL MODEL CLASSIFICATION.....	10
TABLE 3.1 SURFACE WATER QUALITY MODELS.....	18
TABLE 3.2 VARIABLE DESCRIPTION RELATED TO PHYTOPLANKTONIC ALGAE.....	26
TABLE 3.3 VARIABLE DESCRIPTION RELATED TO NITROGEN CYCLE.....	27
TABLE 3.4 VARIABLE DESCRIPTION RELATED TO PHOSPHORUS CYCLE.....	28
TABLE 3.5 VARIABLE DESCRIPTION RELATED TO CARBONACEOUS BOD.....	28
TABLE 3.6 VARIABLE DESCRIPTION RELATED TO DISSOLVED OXYGEN.....	29
TABLE 3.7 VARIABLE DESCRIPTION RELATED TO ATMOSPHERIC REAERATION COEFFICIENTS.....	31
TABLE 3.8 VARIABLE DESCRIPTION RELATED TO ARBITRARY NONCONSERVATIVE CONSTITUENT.....	33
TABLE 3.9 OBLIGATORY DATA FOR EACH PARAMETER TO BE MODELED.....	35
TABLE 3.10 TEMPERATURE CORRECTION FACTORS (RATE COEFFICIENTS).....	35
TABLE 3.11 REACH IDENTIFICATION AND RIVER/MILE KILOMETER DATA.....	35
TABLE 3.12 COMPUTATIONAL ELEMENTS FLAG FIELD DATA.....	35
TABLE 3.13 HYDRAULICS DATA.....	36
TABLE 3.14 TEMPERATURE AND LOCAL CLIMATOLOGICAL DATA.....	36
TABLE 3.15 BOD AND DO REACTION RATE CONSTANTS DATA.....	36
TABLE 3.16 THE VARIABLE INPUT DATA SETS.....	37
TABLE 3.17 INPUT SCREEN SEQUENCE IN QUAL2E WINDOWS INTERFACE.....	42
TABLE 3.18 COMPUTATIONAL ELEMENTS CODES.....	44
TABLE 3.19 GLOBAL KINETICS PARAMETERS.....	47
TABLE 3.20 THETA VALUES (TEMPERATURE CORRECTION FACTORS).....	48
TABLE 3.21 FLOW AUGMENTATION DATA.....	48
TABLE 3.22 DISCHARGE COEFFICIENTS DATA.....	49
TABLE 3.23 TRAPEZOIDAL CHANNELS DATA.....	49

TABLE 3.24	REACH VARIABLE CLIMATOLOGICAL DATA.....	50
TABLE 3.25	BOD AND DO REACTION RATE CONSTANTS DATA.....	50
TABLE 3.26	REAERATION OPTIONS.....	51
TABLE 3.27	N AND P COEFFICIENTS DATA.....	51
TABLE 3.28	ALGAE AND OTHER COEFFICIENTS DATA.....	52
TABLE 3.29	INITIAL CONDITIONS DATA.....	52
TABLE 3.30	HEADWATER DATA.....	53
TABLE 3.31	DAM REAERATION COEFFICIENTS DATA.....	54
TABLE 3.32	ADAM AND BDAM COEFFICIENTS.....	54
TABLE 3.33	INPUT VARIABLES FOR SENSITIVITY ANALYSIS.....	56
TABLE 3.34	INPUT VARIABLES FOR FIRST ORDER ERROR ANALYSIS AND MONTE CARLO SIMULATION.....	56
TABLE 4.1	POPULATION OF RESIDENTIAL AREAS IN THE GEDIZ BASIN (AS OF 1990).....	61
TABLE 4.2	CHARACTERISTICS OF THE DEMIRKÖPRÜ DAM AND RESERVOIR.....	62
TABLE 4.3	CHARACTERISTICS OF THE MARMARA LAKE.....	62
TABLE 4.4	THE GROUNDWATER POTENTIAL OF THE GEDIZ BASIN.....	63
TABLE 4.5	STREAMGAGING STATIONS IN THE GEDIZ RIVER BASIN.....	66
TABLE 4.6	WATER QUALITY SAMPLING SITES ALONG THE GEDIZ RIVER.....	68
TABLE 4.7	RIVER WATER QUALITY CLASSES DETERMINED ACCORDING TO PHYSICAL AND INORGANIC CHEMICAL PARAMETERS, ORGANIC PARAMETERS AND INORGANIC POLLUTION PARAMETERS.....	69
TABLE 4.8	RIVER WATER QUALITY CLASSES DETERMINED BY BACTERIOLOGICAL PARAMETERS.....	70
TABLE 5.1	QUAL2E SIMULATION DATA SET.....	72
TABLE 5.2	STREAM SYSTEM DATA SET.....	73
TABLE 5.3	COMPUTATIONAL ELEMENTS TYPE DATA SET.....	73
TABLE 5.4	POINT LOAD IDENTIFICATION DATA SET.....	74
TABLE 5.5	WATER QUALITY DATA SET.....	75
TABLE 5.6	GEOGRAPHICAL AND CLIMATOLOGICAL DATA SET.....	76
TABLE 5.7	REACH NUMBERS FOR DO/BOD TO BE PLOTTED.....	76
TABLE 5.8	OBSERVED DISSOLVED OXYGEN DATA SET.....	76

TABLE 5.9	GLOBAL KINETICS DATA SET.....	77
TABLE 5.10	TEMPERATURE CORRECTION FACTORS.....	77
TABLE 5.11	CROSS-SECTIONAL AREAS AND Q-H VALUES FOR THE SELECTED REACHES.....	78
TABLE 5.12	THE HYDRAULIC COMPUTATIONS FOR THE BAKLACI STREAMGAGING STATION ACCORDING TO THE ANNUAL REPORTS OF EIE.....	79
TABLE 5.13	THE HYDRAULIC COMPUTATIONS FOR THE URGANLI STREAMGAGING STATION ACCORDING TO THE ANNUAL REPORTS OF EIE.....	79
TABLE 5.14	THE HYDRAULIC COMPUTATIONS FOR THE MEDAR STREAMGAGING STATION ACCORDING TO THE ANNUAL REPORTS OF EIE.....	80
TABLE 5.15	THE HYDRAULIC COMPUTATIONS FOR THE KILLIK STREAMGAGING STATION ACCORDING TO THE ANNUAL REPORTS OF EIE.....	80
TABLE 5.16	THE HYDRAULIC COMPUTATIONS FOR THE MENEMEN STREAMGAGING STATION ACCORDING TO THE ANNUAL REPORTS OF EIE.....	81
TABLE 5.17	HYDRAULIC AND CLIMATOLOGICAL DATA SET.....	81
TABLE 5.18	BOD/DO REACTION RATE CONSTANTS DATA SET.....	82
TABLE 5.19	N, P, ALGAE AND OTHER COEFFICIENTS DATA SET.....	82
TABLE 5.20	THE INCREMENTAL FLOW DATA SET.....	83
TABLE 5.21	HEADWATER DATA SET.....	83
TABLE 5.22	DOMESTIC WASTEWATER DISCHARGES IN THE BASIN.....	84
TABLE 5.23	QUALITY VALUES OF THE MODELED VARIABLES.....	84
TABLE 5.24	POINT LOAD DATA SET.....	84
TABLE 5.25	GLOBAL CLIMATOLOGICAL DATA SET.....	85
TABLE 5.26	INPUT DATA FOR WINTER.....	86
TABLE 5.27	INPUT DATA FOR SPRING.....	86
TABLE 5.28	INPUT DATA FOR SUMMER.....	86
TABLE 5.29	INPUT DATA FOR AUTUMN.....	86
TABLE 5.30	INPUT INCREMENTAL FLOW DATA FOR WINTER.....	87
TABLE 5.31	INPUT INCREMENTAL FLOW DATA FOR SPRING.....	87
TABLE 5.32	INPUT INCREMENTAL FLOW DATA FOR SUMMER.....	88
TABLE 5.33	INPUT INCREMENTAL FLOW DATA FOR AUTUMN.....	88

LIST OF FIGURES

	Page
FIGURE 2.1 ENVIRONMENT AND DECISION MAKING.....	5
FIGURE 2.2 MODELING AND DECISION MAKING PROCESSES IN WATER RESOURCES MANAGEMENT.....	8
FIGURE 2.3 MODEL EVALUATION PROCESS.....	9
FIGURE 2.4 MATHEMATICAL MODELING CONCEPT.....	10
FIGURE 2.5 WATER QUALITY MODELING SYSTEM.....	12
FIGURE 2.6 GENERAL FLOW CHART FOR A WATER QUALITY MODEL.....	14
FIGURE 2.7 STREAM MODELING.....	15
FIGURE 3.1 DISCRETIZED STREAM SYSTEM.....	21
FIGURE 3.2 THE MAJOR INTERACTIONS IN QUAL2E.....	25
FIGURE 3.3 FLOW SCHEME OF QUAL2E MODEL EXECUTION.....	43
FIGURE 4.1 FLOW OBSERVATION STATIONS OF EIE AND DSL.....	67
FIGURE 4.2 THE WATER QUALITY OBSERVATION STATIONS OF DSL.....	68
FIGURE 5.1 THE RIVER REACHES.....	71
FIGURE 5.2 THE LOCATIONS OF DOMESTIC WASTEWATER DISCHARGES.....	74
FIGURE 5.3 SCHEMATIZED RIVER SYSTEM.....	75
FIGURE 5.4 FLOW VERSUS DISTANCE GRAPHS; (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	90
FIGURE 5.5 BOD (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	90
FIGURE 5.6 DO (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	91
FIGURE 5.7 SS (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	92
FIGURE 5.8 EC (μ MHO/CM) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	92
FIGURE 5.9 ORGANIC NITROGEN (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	93
FIGURE 5.10 AMMONIA NITROGEN (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	93

FIGURE 5.11 NITRITE NITROGEN (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	94
FIGURE 5.12 NITRATE NITROGEN (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	94
FIGURE 5.13 ORGANIC PHOSPHORUS (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	95
FIGURE 5.14 DISSOLVED PHOSPHORUS (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	96
FIGURE 5.15 TOTAL PHOSPHORUS (SUM-P) (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	96
FIGURE 5.16 TOTAL NITROGEN (SUM-P) (MG/LT) (A) ON THE MAIN STREAM, (B) ON THE TRIBUTARY.....	97
FIGURE 5.17 BOD (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	98
FIGURE 5.18 DISSOLVED OXYGEN (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	99
FIGURE 5.19 SUSPENDED SOLIDS (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	101
FIGURE 5.20 EC (μ MHO/CM) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	102
FIGURE 5.21 ORGANIC NITROGEN (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	103
FIGURE 5.22 AMMONIA NITROGEN (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	105

FIGURE 5.23 NITRITE NITROGEN (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	106
FIGURE 5.24 NITRATE NITROGEN (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	107
FIGURE 5.25 ORGANIC PHOSPHORUS (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	108
FIGURE 5.26 DISSOLVED PHOSPHORUS (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	109
FIGURE 5.27 SUM-P (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	110
FIGURE 5.28 SUM-N (MG/LT) ON THE MAIN STREAM; (A) WINTER, (B) SUMMER, (C) SPRING, (D) AUTUMN; AND ON THE TRIBUTARY; (E) WINTER, (F) SUMMER, (G) SPRING, AND (H) AUTUMN.....	111

CHAPTER ONE

INTRODUCTION

In recent years, population increase and industrial growth have led to serious environmental problems. These problems lead not only to economic losses but also to several adverse effects on life conditions on earth. Thus, all communities, including managers, engineers, decision-makers and the society itself, are in search of better means of protecting and improving the quality of the environment.

The largest area where environmental pollution occurs is water resources. Most river basins suffer from the degraded quality of surface waters. Thus, water resources planning and management must now be based on optimum decisions. Such an approach requires better tools to aid in the decision-making process. Among these tools are mathematical models which have found a wide area of application in resource management studies. Modeling has two basic purposes:

- a. identification of the basic mechanisms that underlie physical processes;
- b. development of management alternatives and selection of the best strategy in protecting and controlling the environment.

On the other hand, water resources problems and the required solutions have become highly complex such that it is now difficult both to identify among the numerous causes of pollution and to select the best management strategy. Recent advances in the computer technology have provided significant facilities in handling these problems so that most mathematical models have now become computer-based simulation models. With such models, it is possible to investigate large numbers of variables, processes and alternative management decisions. Furthermore, once

a computer-based simulation is developed, management scenarios can be developed to infer on consequences of decisions made.

In most developed countries, one of the most widely used computer models is QUAL2E which serves to simulate surface water quality along river courses. It is not only a simulation model but also a planning model since results of alternative management decisions can be evaluated once the physical system is identified in the model.

The objective of the presented study is to investigate the capabilities and properties of QUAL2E in simulating surface water quality and then to apply it to a test basin in Turkey. To this end, the model software is studied to identify its basic characteristics and requirements. Next, it is applied to the case of the Gediz river basin which, in recent years, has become significantly degraded in its river water quality. Several investigations are carried out by different agencies and institutions to solve the water pollution problem in the basin. However, the use of mathematical simulation models have not been consulted to in any of these studies. Thus, it is intended in this study to present the application of a water quality model in identification of physical processes that underlie water quality problems in the basin.

The basic problems encountered in application of the model are related to data requirements. It has been found that appropriate data that represent the physical conditions in the basin are not adequate. Even the water quality data that could be input to the model were found to be sufficient only for the year 1983. Thus, the results of model run represent the quality conditions of the river as of 1983. Furthermore, significant data are required to calibrate the model parameters for Gediz basin. However, retrieval of such data require an extensive data collection program, which could not be realized within the framework of this study. Thus, the model is run with default values of most parameters. Accordingly, the results of the application do not realistically represent the case of Gediz. Nevertheless, if appropriate and adequate data could be provided, it will be possible to produce effective simulations of water quality in the basin. It is expected that such applications can be further developed and that QUAL2E can be used as an effective decision-making tool for future management practices in the basin.

In the next section, the use of computer-based simulation models in environmental management is discussed. Among them, the role of environmental monitoring in decision-making

process is emphasized. The guidelines for the model selection and some basic features of mathematical modeling are also introduced in general and water quality modeling in particular. Chapter 3 summarizes the basic properties of the QUAL2E model. In this sense, first theoretical background of the model is presented; then data requirements and output files are introduced. Finally, program modules and data loading properties are summarized. Chapter 4 introduces basic characteristics of the Gediz river basin as the test case. These characteristics are classified as geological, climatological, demographical, water and land resources and water potential. Chapter 5 presents the application of the model to the annual and seasonal values of water quality variables observed in the basin. In order to apply the model to the test case, the input data and default values of the model are prepared and loaded. Then the model is run according to those inputs. Outputs of the model are received both in graphical and as numerical values. Chapter 6 summarizes the basic results derived by model application.



CHAPTER TWO

THE USE OF MATHEMATICAL MODELS IN ENVIRONMENTAL MANAGEMENT

2.1 General

Population growth leads to increased demands on natural resources and hence to increased level of environmental problems. The quality of life depends on the availability of natural resources and on favorable conditions of the environment. Especially in the second half of this century, the development of higher life standards, population and the adverse changes in the present natural balance due to increased consumption have led to serious environmental problems. These problems have essentially occurred by the increase of pollutant loads discharged into natural water systems. These loads directly destroy the dynamic balance of the aquatic ecologic system.

The potential contamination sources leading to environmental degradation are (Wrobel & Brebbia, 1991):

- a) Sewage discharges of both domestic and industrial wastes,
- b) Sewage sludge disposal at sea,
- c) Cooling water discharges from coal-fired and nuclear power stations,
- d) Industrial and radio-active wastes from chemical plants and nuclear power stations,
- e) Intensive farming of both crops on land and fish in coastal and estuarine waters,
- f) Poor flushing of harbors and marinas,
- g) Low retention times of lakes and reservoirs.

On the other hand, environmental systems are large scale, complex systems involving diverse characteristics such as (Gordon, 1985):

- a) A large number of decision variables,
- b) A large number of components (subsystems),
- c) A complex and often non-linear functional input/output relationships;
- d) Risks and uncertainties;
- e) A hierarchical organizational structure;
- f) Multiple, competing and conflicting objectives;
- g) Multiple decision makers.

The solution to environmental problems is based on two main requirements; one is the establishment of a sound management system and the second is the selection of the most appropriate management strategy (Özer & Alpaslan, 1985). This means that the environment has to be protected, and this protection has to be realized by developing reliable management decisions and plans.

Decision-making for environmental management is based on management objectives and scientific research which involves modeling as the basic tool. Figure 2.1 shows the basic relationships between the environment and the decision-making process (Uslu, Harmancıoğlu & Alpaslan, 1984).

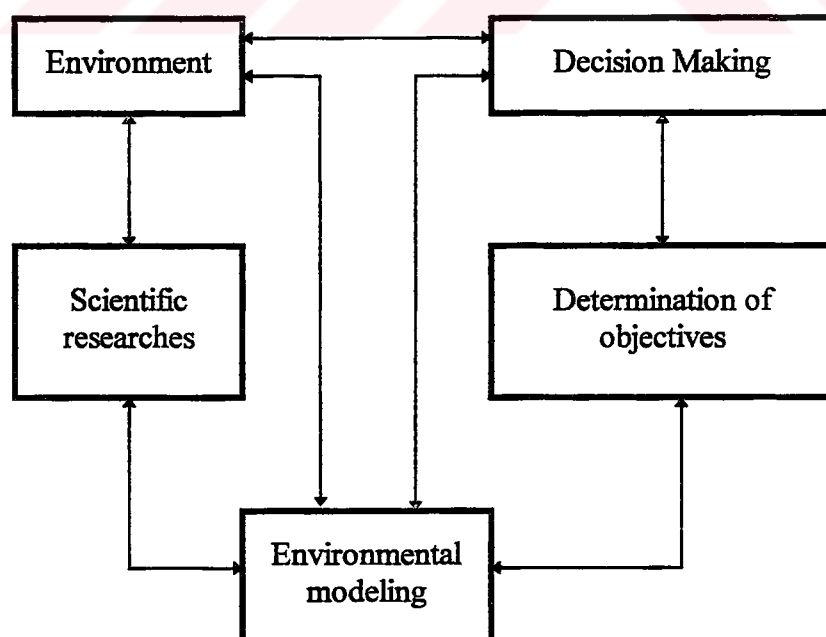


Figure 2.1 Environment and Decision Making.

Decision making on natural events requires the identification of the environmental system, which can be best accomplished by mathematical modeling. Every event that can be explained mathematically can be easily evaluated at every scale. On the other hand, environmental systems are highly complex due to the presence of numerous relevant processes and constraints. This leads the possibility of several alternative solutions that need to be investigated. Such multi-event, multi-objective and multi-solution problems can only be solved by the aid of computers since most people cannot intuitively analyze more than a few variables at one time. Consequently, most mathematical models developed today are computer-based models which have become effective tools in decision-making for environmental management. Essentially, all events that can be expressed mathematically can be transformed into a computer model.

The complexity of environmental problems does not only stem from natural and technological factors; it also involves political, social, legal and economic aspects which can be incorporated into a computer-based mathematical model.

2.2 Models

Mathematical models are empirically or analytically developed mathematical expressions that describe the behavior of a natural system. They help to identify the basic properties of such a system and provide a tool with which environmental quality can be studied quantitatively (Özmenek, 1996).

Mathematical models essentially describe the real system with mathematical expressions that are derived from the basic underlying concepts. They are important tools that help to identify and evaluate the present conditions in a river body (Ergen, 1995).

With the availability of large scale digital computers, mathematical models have received increasing attention (Canter, 1985). In recent times, modeling has become common practice in almost every field of water quality analysis. Such environmental models include both deductive and inductive type approaches based on conceptual and empirical components. These models can provide us with certain quantitative information. With this information, the behavior of a natural event that is modeled can be predicted under several assumed

conditions. Consequently, the most consistent decisions can be made according to the expected behavior of a natural system. The main issue in the use of computer-based models is that a model must represent the real event with maximum sensitivity.

Environmental models can be classified as technological and decision models. Technological models define the micro events and are established according to main concepts like as biochemistry and hydrodynamics. On the other hand, decision models are macro level models that include political, economical and social factors, long term planning, decision making and prediction.

While technological models formulate the physical, chemical and biological events in nature and engineering systems, decision models include also economical and political factors. Decision models can be subdivided into optimization and simulation models. On the other hand, technological models are the sub-systems of decision models that produce the objective functions and boundary conditions of decision models (Fleming, 1977).

The main objective of effective environmental management is to satisfy the demand, given possibilities and limitations of water supply. The various steps involved in water resources management, from problem formulation to decision making, are described in Fig. 2.2 (Ganoulis, 1994). This figure shows the relationship between the modeling procedure and the decision-making process.

In the selection and use of models, the following items are used as guidelines:

- a. The first step is to define the problem and to determine both what information is needed and what questions need to be answered,
- b. The simplest method must be used to provide the answers to questions relevant to the problem,
- c. The simplest model that will yield adequate accuracy must be selected,
- d. One must not try to fit the problem to a model, but select a model that fits the problem,
- e. Complexity must not be confused with accuracy,
- f. One must always question whether increased accuracy is worth the increased effort and cost,
- g. The assumptions underlying the model must not be forgotten, and the modeler should not read more significance into the simulation results than is actually there.

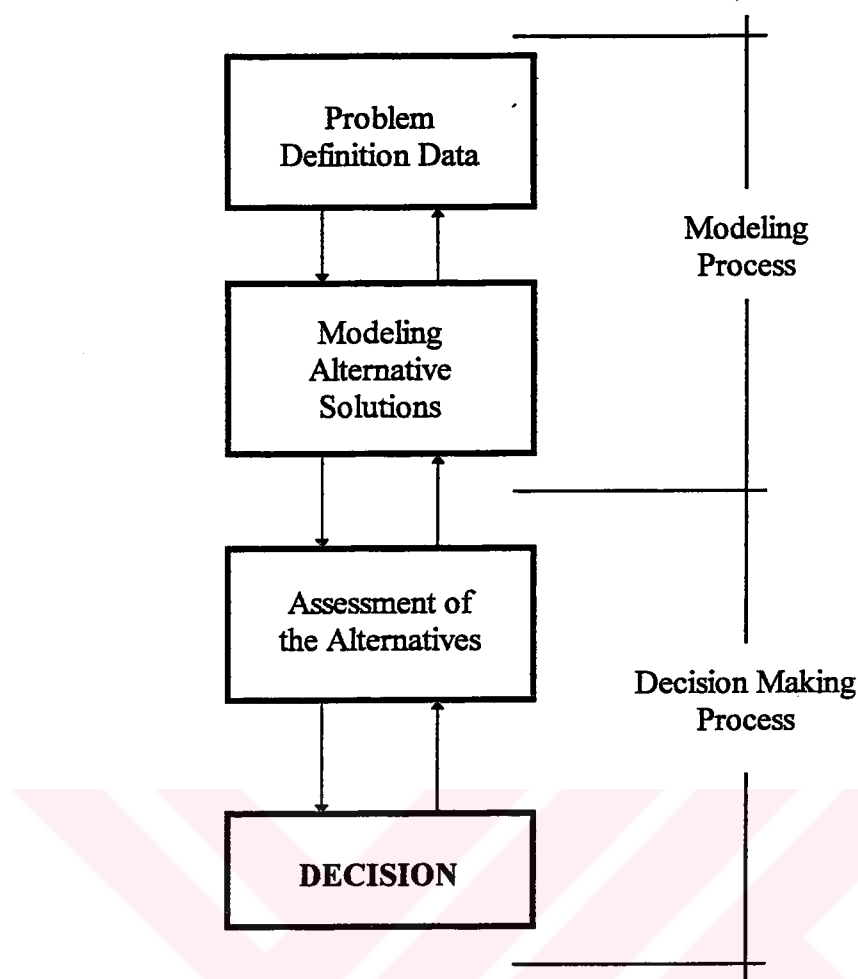


Figure 2.2 Modeling and Decision Making Processes in Water Resources Management.

First of all, every model must be carefully evaluated before it is used in order to ensure that the proper model is chosen for the selected task. The steps on this analysis are given in Fig. 2.3 (Gordon, 1985).

2.2.1 Basics of Mathematical Modeling

A mathematical model is defined as a model which can be solved mathematically. Since most of the equations involved are complex, a mathematical model usually involves the simultaneous solution of several differential equations by numerical techniques with the help of digital computers.

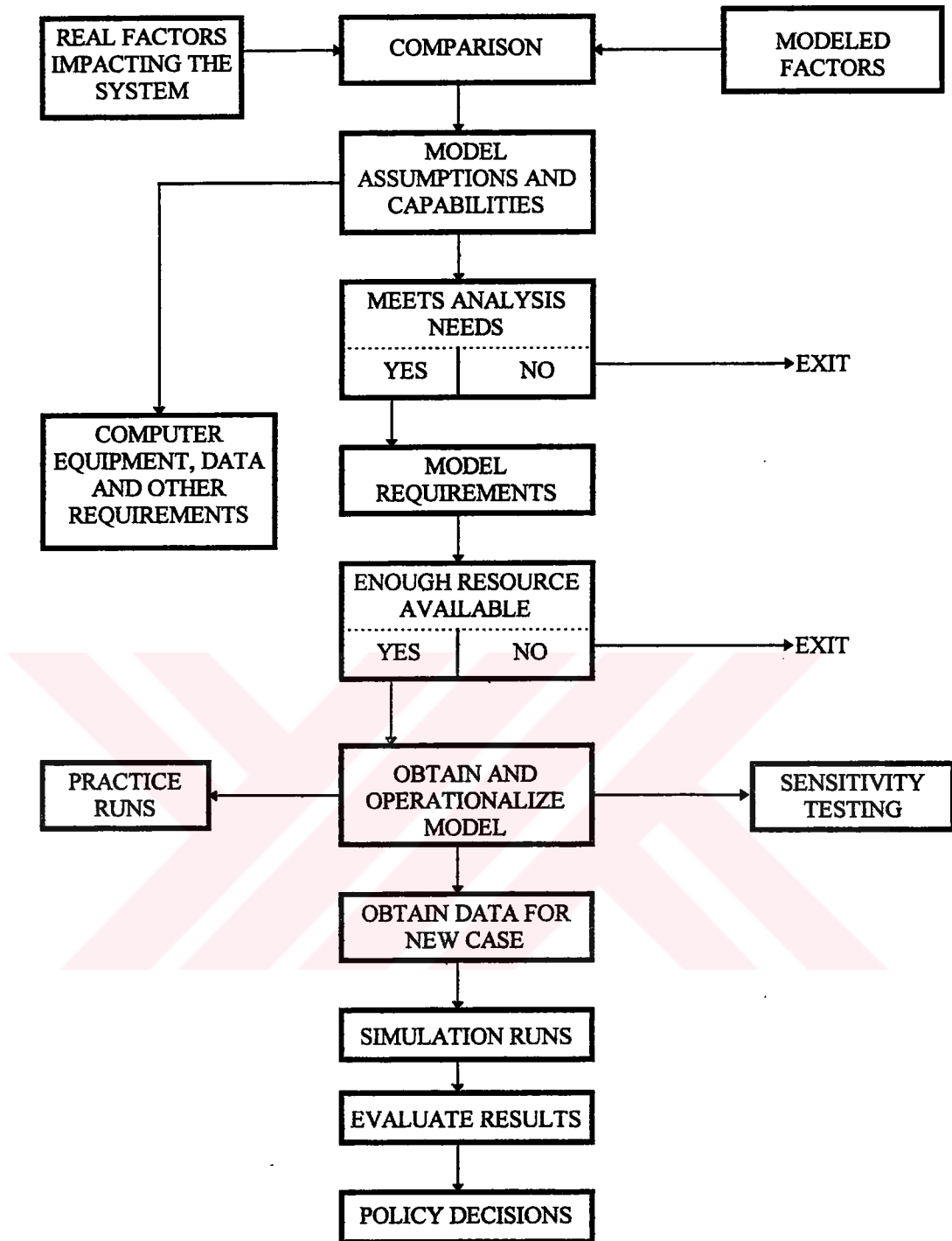


Figure 2.3 Model Evaluation Process.

Mathematical modeling usually deals with the techniques of solving basic equations. The basic equations used in mathematical modeling to study the movement of water and sediment through rivers are:

- a) Flow continuity equation
- b) Flow momentum equation
- c) Sediment continuity equation
- d) Sediment transport equation

The conceptual framework for mathematical modeling can be summarized as in Fig. 2.4.

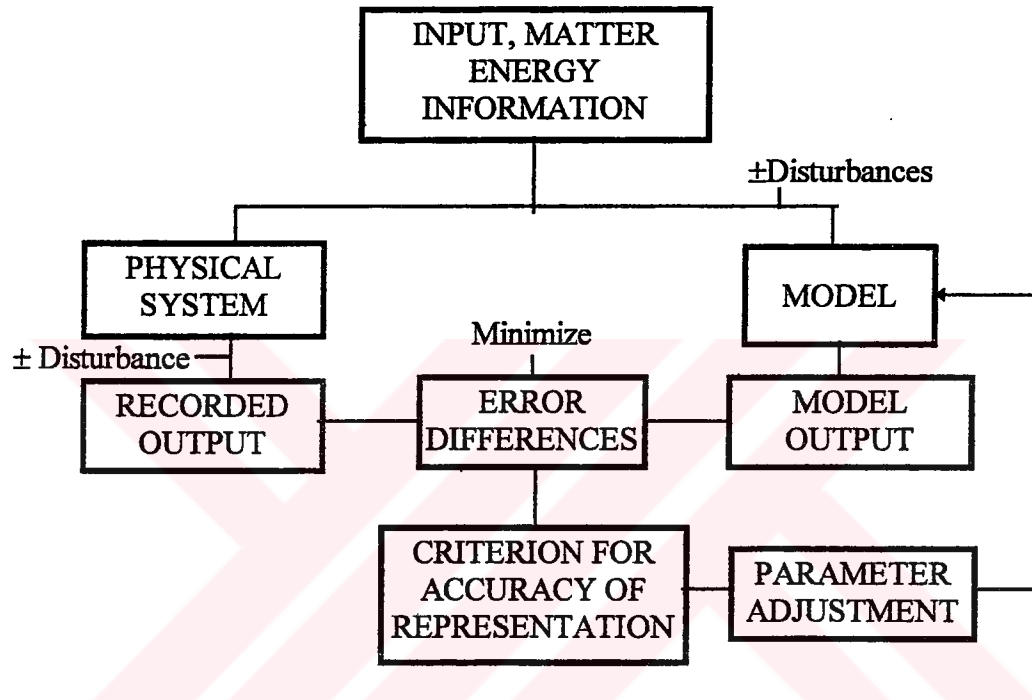


Figure 2.4 Mathematical Modeling Concept.

Mathematical models that are used especially in environmental engineering can be classified as given in Table 2.1 (Uslu, Çelebi, Türkman & Şengül, 1983).

Table 2.1 Mathematical Model Classification.

ENVIRONMENTAL MODELS		
Based on Structure	Based on Objective	Decision Models
a. Linear - Non linear	a. Technological Models	a. Optimization
b. Stochastic - Deterministic	- Urban Infrastructural Models	b. Simulation
c. Empirical - Conceptual	- Treatment Models	
d. Lumped - Distributed	b. Natural Systems Models	
e. Static - Dynamic	- Ecological Models	
	- Transport - Mixing Models	

Mathematical models can also be classified as hydraulic models and hydrologic models; the former consider the mechanics of the flow, whereas the latter utilize the continuity of the flow. Mathematical hydraulic models can be one-, two-, or three- dimensional. One-dimensional models use cross-sectional average flow parameters and consider the variations of the parameters in both the longitudinal and transverse directions. Two-dimensional models consider the variations in longitudinal and vertical directions while assuming homogenous conditions along the transverse direction. Three-dimensional models use “point” flow parameters and consider the longitudinal and transverse, as well as vertical directions.

Hydraulic models can be classified according to the time variation of the flow as steady flow models and unsteady flow models. They can also be classified according to the geometric boundary condition as fixed boundary models and loose boundary models. Fixed boundaries can be rigid or flexible; the latter rarely occurs in rivers. Loose boundaries usually involve erosion, deposition and transport of cohesive and non cohesive sediment.

On the other hand, mathematical models can be classified according to the solution techniques as analytical models, graphical models and numerical models. Graphical models solve the problem graphically. Numerical models require numerical procedures to obtain solutions.

2.3 Water Quality Modeling

The term “water quality” refers to the condition, or state of a given parcel of water. Usually it is described by such measurements and indicators as temperature, coliform count, dissolved oxygen, biochemical oxygen demand (BOD), total dissolved solids and any cations and anions.

Water quality modeling is the mathematical description of the concentration of parameters that define pollution with respect to time and space (Uslu & Türkman, 1987). Water quality modeling helps to describe the water quality quantitatively as shown in Fig. 2.5.

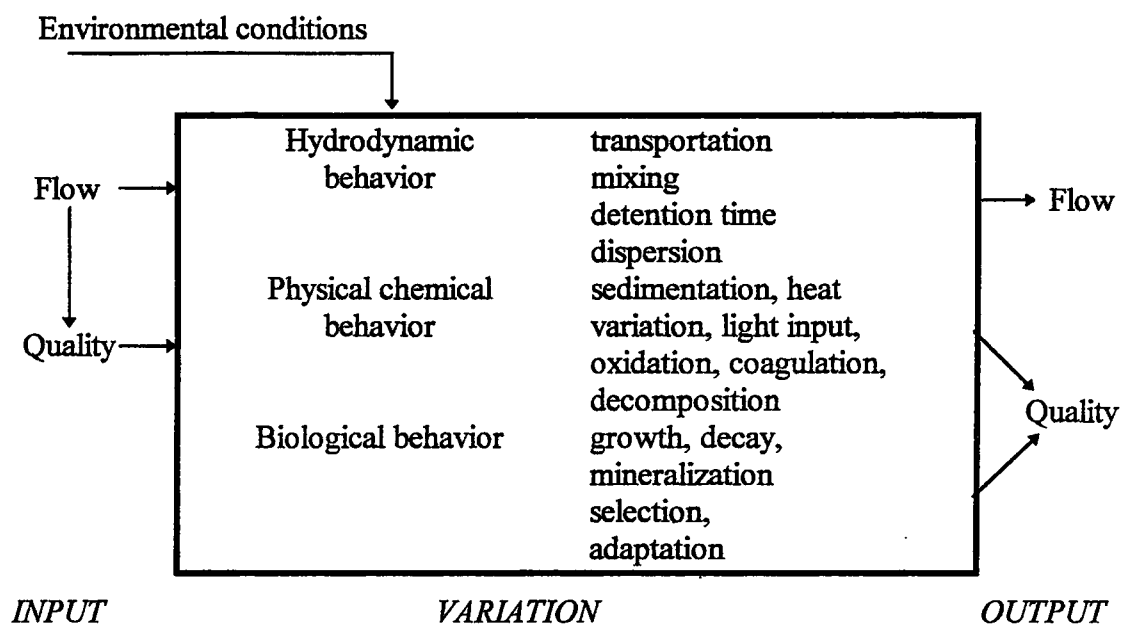


Figure 2.5 Water Quality Modeling System.

The choice of water quality parameters to be modeled is dependent upon the objectives of water use such as;

- a) domestic water use,
- b) industrial process water,
- c) industrial cooling,
- d) recreation,
- e) fishery maintenance,
- f) esthetic preservation and
- g) irrigation.

Water quality models include the synthesis of natural events with mathematical functions. There are a lot of water quality models developed in this framework. The best model and the necessary database for the solution of a definite problem are dependent on the objective of the study. In the selection of a model, there are some limiting factors such as time and economical sources. Today, most of the water quality models are developed for river systems that are exposed to point loads. On the other hand, non-point source pollution has become important in recent years besides point source pollution. For this reason, models are applied to rivers that are exposed to non-point loads, and outputs of these models can be used as inputs for the water quality models of receiving media.

Surface waters are not only the sources of water supply but they also function as sinks for used water. They receive polluted waters from:

- a) point source discharges of treated wastewater, i.e., from municipalities and industries,
- b) non-point source flows, i.e., from irrigated agriculture, urban storm water runoff.

Modeling of surface waters as the receiving media serves several purposes. First of all, computer models are valuable tools that can be used in making water quality management decisions. The objective of water quality modeling is to study the behavior of natural systems in response to external inputs. As a first step in the modeling process, it is important to be able to predict the hydraulic performance of the system.

Furthermore, mathematical models are used to set effluent limitations on industrial and municipal wastewater discharges. By using these models, it is possible to define various alternatives to meet water quality objectives. These alternatives include various levels of wastewater treatment, flow augmentation, moving the point of discharge to a larger stream or artificial instream aeration. The other important use of models includes the determination of the sensitivity of model outputs to estimated reaction coefficients and other variables that possibly may have been estimated.

The modeling of water quality changes in streams, rivers, and oceans subject to both natural and anthropogenic inputs constitutes a major aspect of water quality management. The development of water quality models involves the application of materials balances and kinetic expressions to describe the physical system. By modeling river systems it is possible to assess the assimilative capacity of these systems and thus to predict the impacts of proposed developments and natural occurrences.

2.4 Types of Water Quality Models

Water quality models in environmental engineering can be classified with respect to different criteria (Uslu & Türkman, 1987):

- a. With respect to the information obtained
 - Empirical (statistical, black box)
 - Deterministic (conceptual)

b. With respect to the dimension of the independent variable

- 1, 2, or 3 dimensional (1D, 2D, 3D)
- Steady state or dynamic in time

c. With respect to the computer system used

- Analog
- Digital

d. With respect to conceptual framework

- Hydrological
- Hydrodynamic
- Physical
- Chemical
- Biological
- Ecological

A general water quality model flowchart can be given as in Fig. 2.6.

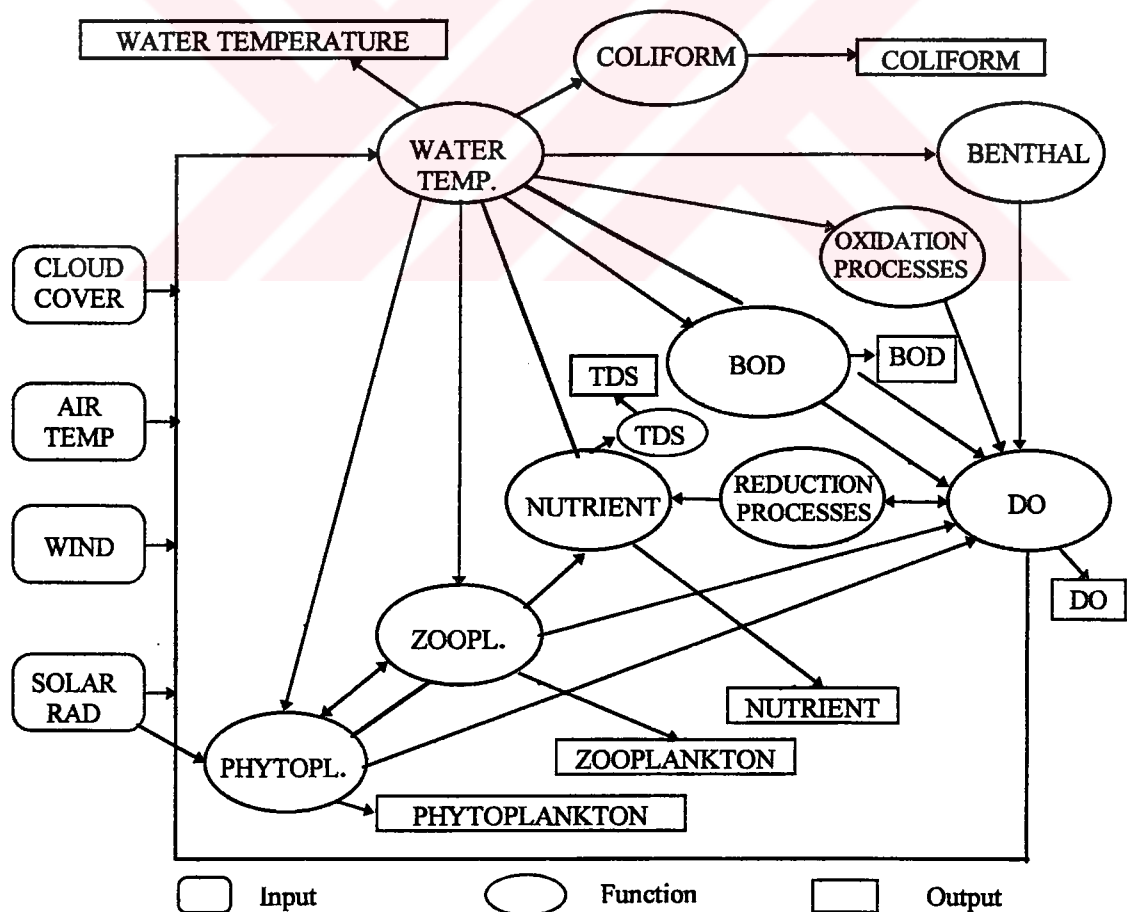


Figure 2.6 General Flow Chart for a Water Quality Model.

Figure 2.7 summarizes the general process of stream modeling. Each stream segment I is distinguished by having a unique set of physical properties which might affect the dispersion and degradation of pollutants. These include depth, width, slope, velocity, and discharge rate (Gordon, 1985).

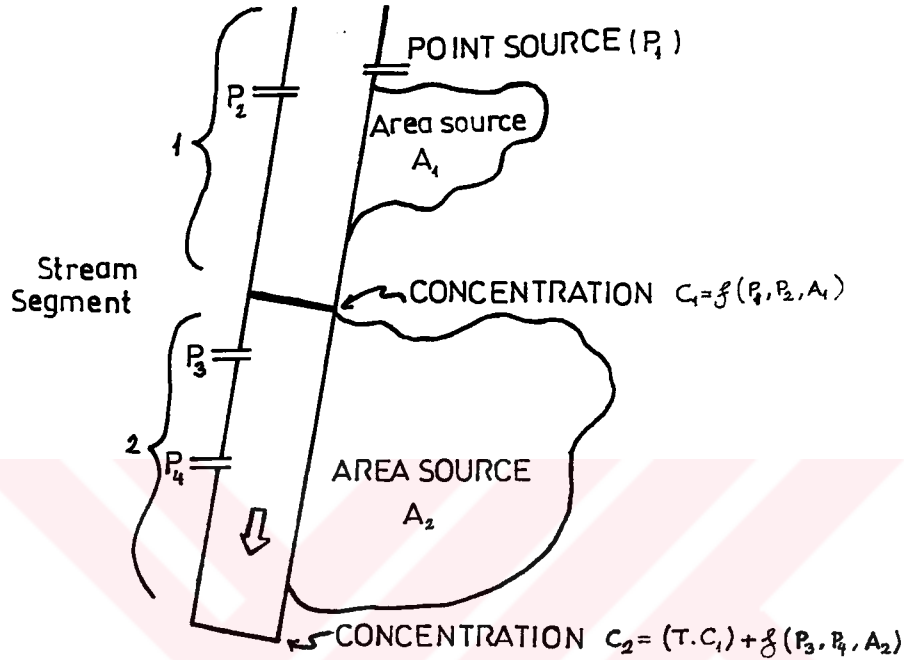


Figure 2.7 Stream Modeling.

Each stream segment may also have a set of natural and human pollutant contributions. These may be from point sources, P_i , or non-point, spatial sources, A_i (Gordon, 1985). Thus, the basic structure of a model may be summarized by the following equations:

$$\begin{aligned} C_i &= f(P_i, A_i, T_{i-1}) \\ T_{i-1} &= f(S_i, R_i) \end{aligned} \quad (2.1)$$

where;

- C_i : the concentration of pollutant C in segment i ,
- P_i : the point source contribution of pollutants in segment i ,
- A_i : the area source contribution of pollutants in segment i ,

- T_{i-1} : the transfer function of pollutants from the upstream segment,
 S_i : the stream parameters affecting the transfer rate,
 R_i : the chemical reactions affecting the transfer,

In applying such a model, alternative choices exist in representation of the nature of system (Gordon, 1985):

- a. A *steady state model*, is a model that assumes time-invariant inputs, measurements and states.
- b. A *dynamic model*, allows the explicit changes of the variables and states of the system through time.
- c. A *deterministic model*, assumes that the value of all variables can be computed exactly and that all values are known.
- d. A *probabilistic model*, assumes that at least some parameters are unpredictable, usually within some range or known distribution and with some probability of occurrence.

In this study, the steady state modeling case will be presented by a computer model developed by EPA - Environmental Protection Agency. The model is called QUAL2E Water Quality Model which is a deterministic receiving media model that simulates water quality along water courses. The basic properties of this model are described in the next section.

CHAPTER THREE

DESCRIPTION OF THE QUAL2E MODEL

3.1 General

QUAL-I was initially developed in 1960s by the Texas Water Development Board. Then several improved versions of the model were introduced by EPA, and after extensive review and testing, the QUAL-II series became widely used. QUAL2E is provided by the Environmental Protection Agency's Center for Exposure Assessment Modeling (CEAM) (Brown & Barnwell, 1987).

The Enhanced Stream Water Quality Model QUAL2E is a comprehensive and versatile stream water quality model. The model can be used as a water quality planning tool. QUAL2E-UNCAS is an enhancement to QUAL2E that allows the user to perform uncertainty analysis.

There are DOS and WINDOWS versions of QUAL2E model. The WindowsTM Interface used in this study was developed in order to make the data input and model execution easier. The Windows interface integrates the QUAL2E model and data handling needs to make the model implementation user friendly (Brown & Barnwell, 1995).

QUAL2E allows the simulation of 15 water quality constituents in a branching stream system using a finite difference solution to the one-dimensional advective-dispersive mass transport and reaction equation. QUAL2E predicts DO, BOD, temperature, and phytoplankton dynamics as affected by nutrients and organic material. It comes with a pre- and post-processor and software that facilitates sensitivity and uncertainty analysis (Donigian, Imhoff & Ambrose, 1995). QUAL2E is one of eleven water quality models that

are documented and available to the public. Table 3.1 summarizes the important model attributes.

Table 3.1 Surface Water Quality Models (Donigian et al., 1995).

Model		Q U A L 2 E	S M P T O X 3	H S P F	W A S P 5	E X A M S	C E Q U A L R I V 1	C E Q U A L W 2	C E Q U A L L I C M	H E C 5 Q	S A L M O N Q	M I K E 1 1
Water body type	Stream, river	X	X	X	X	X	X	X	X	X	X	X
	Lake, reservoir				X	X		X	X	X		
	Estuary	X		X		X	X					
Dimension	1D, Branching	X	X	X	X	X	X	X	X	X	X	X
	2D, X/Y				X	X			X			
	2D, X/Z				X	X		X	X			
	3D, Box				X	X			X			
Time	Steady	X	X			X						
	Quasidynamic	X		X	X	X					X	X
	Dynamic			X	X		X	X	X	X	X	X
Hydro-dynamics	Input	X	X	X	X	X						X
	Simulated			X	X		X	X	X	X	X	X
	Control Struct.			X			X	X	X	X	X	X
Transport	Advection	X	X	X	X	X	X	X	X	X	X	X
	Dispersion	X	X		X	X	X	X	X	X	X	X
	Benthic Exch.		X	X	X	X		X	X	X		
Loading	Input, steady	X	X	X	X	X	X	X	X	X	X	X
	Input, variable			X	X	X	X	X	X	X	X	X
	Simulated			X	X						X	X
Other	Preprocessor	X	X		X	X					X	X
	Postprocessor	X	X	X	X	X					X	X
Chemical Processes	First Or. Decay	X	X	X	X	X	X	X	X	X	X	X
	Process kinetics			X	X	X						
	Daughter Prod.			X	X	X						
	Sorption		X	X	X	X					X	
Sediment Processes	Input rates		X	X	X		X		X	X	X	X
	Noncoh. Proc.			X						X	?	
	Cohesive Proc.			X						X	?	
Water Quality Processes	Temperature	X		X			X	X	X	X	X	X
	Salinity	X		X			X	X	X	X	X	X
	Bacteria			X			X	X	X	X	X	X
	DO-BOD	X		X	X		X	X	X	X		
	DO-C balance							X	X			
	N cycle	X		X	X		X	X	X	X	X	X
	P cycle	X		X	X		X	X	X	X	X	X
	Silicon cycle							X	X		X	X
	Phytoplankton	X		X	X		X	X	3	X	X	X
	Zooplankton			X					X		X	
	Benthic algae			X							X	X
	Simulate SOD								X			

In the QUAL2E formulation, the conceptual representation of a stream is a stream reach that has been divided into subreaches or computational elements equivalent to finite differences. For each computational element; hydrologic, heat and materials balance are written in terms of respectively flow (Q), temperature (T) and concentration (C). Both advective and dispersive transport are considered in the materials balance. Mass can be gained and lost from the element by transport processes, external sources and sinks (waste discharges or withdrawals) or by internal sources and sinks (Benthic sources or biological transformations).

The program simulates also changes in flow conditions along the stream by computing a series of steady-state water surface profiles.

The model is applicable to dendrite streams that are well mixed. It assumes that the major transport mechanisms, advection and dispersion, are significant only along the main direction of flow. It allows for multiple waste discharges, withdrawals, tributary flows, and incremental inflow and outflow. It also has the capability to compute required dilution flows for flow augmentation to meet any pre-specified dissolved oxygen level.

The QUAL2E computer program can be operated either as a steady-state or dynamic model. When operated steady-state, the model can be used to study the impact of waste loads on instream water quality and to identify the magnitude and quality characteristics of non-point waste loads by entering the data related to irrigation water to the model. On the other hand, by operating the model dynamically, the user can model the effects of diurnal variations in meteorological data on water quality - primarily dissolved oxygen and temperature - and examine diurnal dissolved oxygen variation caused by algal growth and respiration. However, the effects of dynamic forcing functions, such as headwater flows or point loads, cannot be modeled in QUAL2E.

Prototype representation in QUAL2E consists of dividing a stream in a network of "Headwaters", "Reaches" and "Junctions". The fundamental reason for subdividing sections of a stream into "Reaches" is that QUAL2E assumes that some 26 physical, chemical and biological properties (model input parameters or coefficients) are constant along a "Reach".

The model consists of four main modules. These are:

- AQUAL2 - data preparing program for QUAL2E and QUAL2EU models,
- QUAL2E - main model module,
- QUAL2EU - module for uncertainty analysis,
- Q2PLOT - the graphics module.

These modules will be explained briefly in the following sections (Brown & Barnwell, 1995).

As stated before, in addition to the versions of the model, it is possible to use; DOS version and the WINDOWS version. Because the Windows version has an extensive and increasing usage, this version is introduced and used in the presented study.

3.2 Theoretical Background of QUAL2E

3.2.1 Mass Transport

The primary objective of any stream water quality model development is to produce a tool that has the capability for simulating the behavior of the hydrologic and water quality components of a stream (Brown & Barnwell, 1987). The development of this tool to simulate prototype behavior by applying a mathematical model.

The functional representation of the model includes the formulation of the physical features, processes and boundary conditions into sets of algebraic equations. This involves the definition of each variable and its relationship to all other parameters that characterize the model or its input - output relationships. The general discretized stream system as defined in QUAL2E is shown in Fig. 3.1.

The basic equation solved by QUAL2E is the one dimensional advection - dispersion mass transport equation, which is numerically integrated over space and time for each water quality constituent. This equation includes the effects of advection, dispersion, dilution, constituent reactions and interactions and sources and sinks (Brown & Barnwell, 1987). For any constituent, C, this equation can be written as:

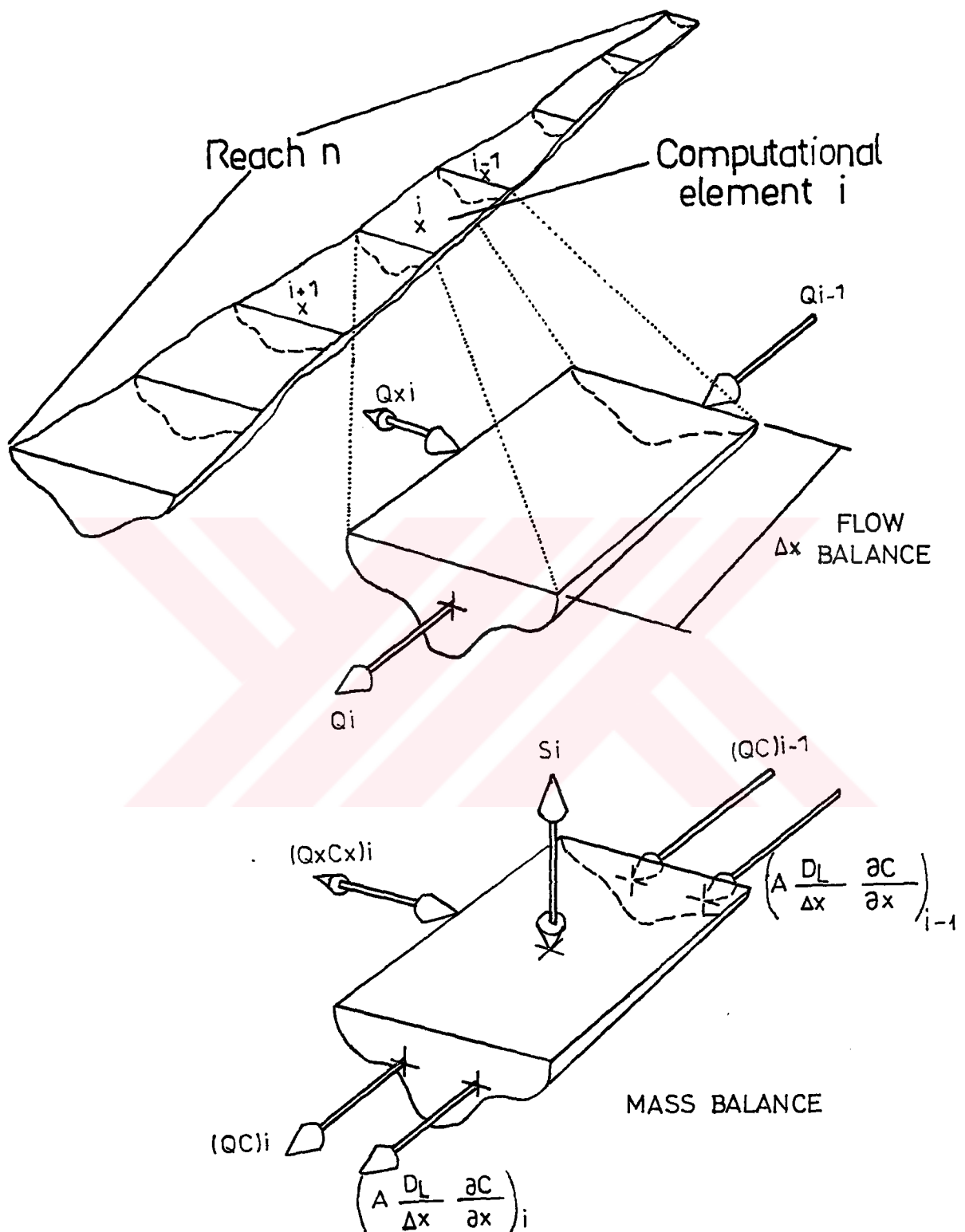


Figure 3.1 Discretized Stream System

$$\frac{\partial M}{\partial t} = \frac{\partial \left(A_x D_L \frac{\partial C}{\partial x} \right)}{\partial x} dx - \frac{\partial (A_x \bar{u} C)}{\partial x} dx + (A_x dx) \frac{dC}{dt} + s \quad (3.1)$$

where;

M	: mass (M)	A_x	: cross-sectional area (L^2)
x	: distance (L)	D_L	: dispersion coefficient ($L^2 T^{-1}$)
t	: time (T)	u	: mean velocity ($L T^{-1}$)
C	: concentration (ML^{-3})	s	: external source or sinks (MT^{-1})

Because $M = VC$, we can write;

$$\frac{\partial M}{\partial t} = \frac{\partial (VC)}{\partial t} = V \frac{\partial C}{\partial t} + C \frac{\partial V}{\partial t} \quad (3.2)$$

where; $V = A_x dx = \text{incremental volume } (L^3)$

If we assume that the flow in the stream is steady with $\partial Q / \partial t = 0$, then the term $\partial V / \partial t = 0$ and Equation 3.2 becomes;

$$\frac{\partial M}{\partial t} = V \frac{\partial C}{\partial t} \quad (3.3)$$

By combining the equations 3.1 and 3.3, we can rearrange them;

$$\frac{\partial C}{\partial t} = \frac{\partial \left(A_x D_L \frac{\partial C}{\partial x} \right)}{A_x \partial x} - \frac{\partial (A_x \bar{u} C)}{A_x \partial x} + \frac{dC}{dT} + \frac{s}{V} \quad (3.4)$$

The terms on the right-hand side of the equation represent, respectively, dispersion, advection, constituent changes, external sources/sinks, and dilution. The dC/dt term refers only to constituent changes such as growth and decay, and should not be confused with the term $\partial C / \partial t$, the local concentration gradient. The latter term includes the effect of constituent changes as well as dispersion, advection, sources/sinks and dilutions.

Under steady-state conditions, the local derivative becomes equal to zero; in other words:

$$\frac{\partial C}{\partial t} = 0 \quad (3.5)$$

QUAL2E assumes that the stream hydraulic regime steady-state or $\partial Q/\partial t = 0$, the hydrologic balance for a computational element can be written as:

$$\left(\frac{\partial Q}{\partial x} \right)_i = (Q_x)_i \quad (3.6)$$

where $(Q_x)_i$ is the sum of the external inflows and/or withdrawals to that element.

3.2.2 Longitudinal Dispersion

The term “dispersion” is generally used for transport associated with spatially averaged velocity variation, as opposed to “diffusion”, which is reserved for transport that is associated primarily with time-arranged velocity fluctuations.

QUAL2E solves the equation of longitudinal dispersion coefficient as (Brown & Barnwell, 1987).

$$D_L = 3.82 K \bar{u} d^{5/6} \quad (3.7)$$

where;

- D_L : longitudinal dispersion coefficient, ft^2/sec
- K : dispersion constant, dimensionless
- n : Manning’s roughness coefficient, dimensionless
- u : mean velocity, ft/sec
- d : mean depth, ft

3.2.3 Flow Augmentation

When the DO concentration in a stream drops below some required target level, such as the state water quality standard for DO, it may be desirable to raise this DO concentration by augmenting the flow of the stream. For this reason, QUAL2E has the following quadratic equation to solve this problem (Brown & Barnwell, 1987):

$$DO_R = DO_T - DO_{min} \quad (3.8)$$

and

$$Q_R = Q_C \left[\frac{DO_R}{DO_T} + 0.15 \left(\frac{DO_R}{DO_T} \right)^2 \right] \quad (3.9)$$

where;

- DO_R : dissolved oxygen concentration required to meet target conditions, mg/l
- DO_T : required target level of DO, mg/l
- DO_{min} : minimum DO concentration (critical level) in the oxygen sag curve, mg/l
- Q_R : amount of flow augmentation required, ft³/sec
- Q_C : flow at the critical point in the oxygen sag curve, ft³/sec

3.2.4 Constituent Reactions and Interrelationships

3.2.4.1 General

In determining the assimilative capacity of a stream, one of the important considerations is its ability to maintain an adequate dissolved oxygen concentration. The QUAL2E computer program includes the major interactions of the nutrient cycles, algal production, benthic and carbonaceous oxygen demand, atmospheric reaeration and their effects on the dissolved oxygen balance. In addition, the computer program includes a heat balance for the computation of temperature and mass balances for conservative minerals, coliform bacteria and non-conservative constituents such as radioactive substances. The major interactions in QUAL2E is given in Fig. 3.2 (Brown & Barnwell, 1987).

The mathematical relationships that describe the individual reactions and interactions are presented in the following sections.

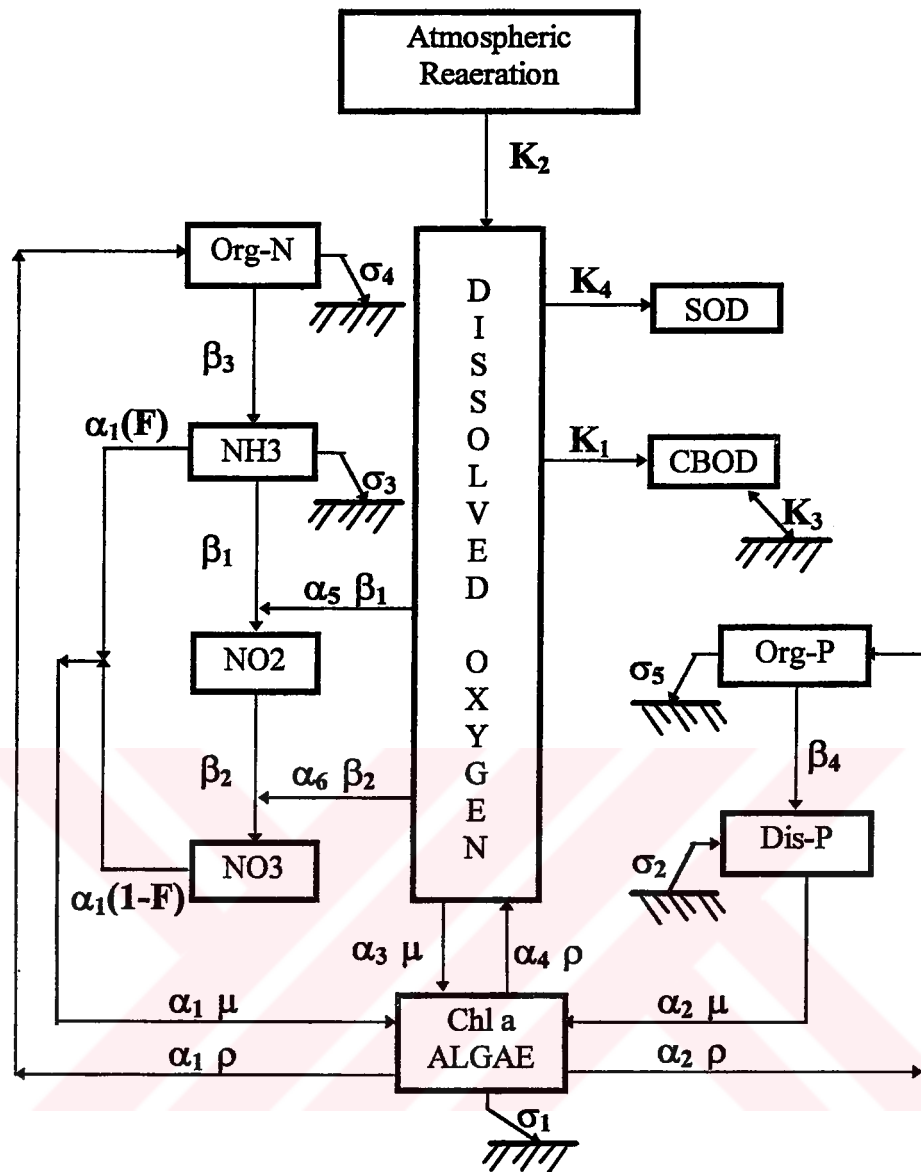


Figure 3.2 The Major Interactions in QUAL2E (Brown & Barnwell, 1987).

3.2.4.2 Phytoplanktonic Algae

Chlorophyll A is modeled as the indicator of planktonic algal biomass in QUAL2E. Chlorophyll A is considered to be directly proportional to the concentration of phytoplanktonic algal biomass. The differential equation that governs the growth and production of algae (Chlorophyll A) is formulated according to the relationship given in Equation 3.10 and the variable descriptions are given in Table 3.2.

$$\frac{dA}{dt} = \mu A - \rho A - \frac{\sigma}{d} A \quad (3.10)$$

Table 3.2 Variable Description Related to Phytoplanktonic Algae (Brown & Barnwell, 1987).

Variable	Description	Units	Range of values	Variable by reach	Temp. dependent
A	Algal biomass concentration	mg/l			
t	Time	day			
d	Average depth	ft			
μ	Algal growth rate	day ⁻¹	1.0-3.0	No	No
ρ	Algal respiration rate	day ⁻¹	0.05-0.5	No	No
σ_1	Algal settling rate	ft/day	0.5-6.0	Yes	Yes

3.2.4.3 Nitrogen Cycle

In natural aerobic waters, there is a stepwise transformation from organic nitrogen to ammonia, to nitrite, and finally to nitrate. The nitrogen cycle in QUAL2E contains all four of these components. The differential equations about transformations from one form to another are shown below and the variable descriptions are given in Table 3.3.

For ammonia nitrogen (N_1);

$$\frac{dN_1}{dt} = \beta_3 N_4 - \beta_1 N_1 + \sigma_3/d - F\alpha_1 \mu A \quad (3.11)$$

For nitrite nitrogen (N_2);

$$\frac{dN_2}{dt} = \beta_1 N_1 - \beta_2 N_2 \quad (3.12)$$

For nitrate nitrogen (N_3);

$$\frac{dN_3}{dt} = \beta_2 N_2 - (1 - F)\alpha_1 \mu A \quad (3.13)$$

And for organic nitrogen (N_4);

$$\frac{dN_4}{dt} = \alpha_1 \rho A - \beta_3 N_4 - \sigma_4 N_4 \quad (3.14)$$

Table 3.3 Variable Description Related to the Nitrogen Cycle (Brown & Barnwell, 1987).

Variable	Description	Units	Range of values	Variable by reach	Temp. dep.
N ₁	the conc. of ammonia nitrogen	mg-N/l			
N ₂	the conc. of nitrite nitrogen	mg-N/l			
N ₃	the conc. of nitrate nitrogen	mg-N/l			
N ₄	the conc. of organic nitrogen	mg-N/l			
α ₁	Fraction of algal biomass	mgN/mgA	0.07-0.09	No	No
β ₁	Rate constant for the biological oxidation of NH ₃ to NO ₂	day ⁻¹	0.10-1.00	Yes	Yes
β ₂	Rate constant for the biological oxidation of NO ₂ to NO ₃	day ⁻¹	0.20-2.0	Yes	Yes
β ₃	Rate constant for the hydrolysis of organic-N to ammonia	day ⁻¹	0.02-0.04	Yes	Yes
σ ₃	Benthos source rate for ammonia nitrogen	mgO/ft ² .d	Variable	Yes	Yes
σ ₄	Organic nitrogen settling rate	day ⁻¹	0.001-0.1	Yes	Yes
μ	Algal growth rate	day ⁻¹	1.0-3.0	No	No
ρ	Algal respiration rate	day ⁻¹	0.05-0.5	No	No
F	Fraction of algal nitrogen uptake from ammonia pool	-			

3.2.4.4 Phosphorus Cycle

Similarly, the phosphorus cycle has two components: Organic phosphorus and Dissolved phosphorus. Organic forms of phosphorus are generated by the death of algae, which then convert to the dissolved inorganic state, where it is available to algae for primary production. Phosphorus discharged from sewage treatment plants is generally in the dissolved inorganic form. The differential equations about transformations of phosphorus from one form to another are given in Equations 3.15 and 3.16 and the variable descriptions are given in Table 3.4.

For organic phosphorus (P₁);

$$\frac{dP_1}{dt} = \alpha_2 \rho A - \beta_4 P_1 - \sigma_5 P_1 \quad (3.15)$$

And for dissolved phosphorus (P₂);

$$\frac{dP_2}{dt} = \beta_4 P_1 + \sigma_2/d - \alpha_2 \mu A \quad (3.16)$$

Table 3.4 Variable Description Related to the Phosphorus Cycle (Brown & Barnwell, 1987)

Variable	Description	Units	Range of values	Variable by reach	Temp. dep.
P ₁	the conc. of organic P	mg-P/l			
P ₂	the conc. of inorg.(diss) P	mg-P/l			
α ₂	Fraction of algal biomass	mgP/mgA	0.01-0.02	No	No
β ₄	Rate constant for the decay of organic P to dissolved P	day ⁻¹	0.10-0.7	Yes	Yes
σ ₂	Benthos source rate for dissolved phosphorus	mgO/ft ² .d	Variable	Yes	Yes
σ ₅	Organic P settling rate	day ⁻¹	0.001-0.1	Yes	Yes
μ	Algal growth rate	day ⁻¹	1.0-3.0	No	No
ρ	Algal respiration rate	day ⁻¹	0.05-0.5	No	No

3.2.4.5 Carbonaceous BOD

Ultimate carbonaceous Biochemical Oxygen Demand (BOD) is modeled as a first-order degradation process in QUAL2E that also takes into account removal by settling and does not affect the oxygen balance:

$$\frac{dL}{dt} = -K_1L - K_3L \quad (3.17)$$

QUAL2E simulates ultimate BOD in the general case; however, the user may choose to use 5-day BOD values for input and output. In this case, the model will make the necessary conversions from 5-day to ultimate BOD. The conversion equation is:

$$BOD_5 = BOD_U[1.0 - \exp(5 * KBOD)] \quad (3.18)$$

The variable descriptions related to this section are given in Table 3.5.

Table 3.5 Variable Description Related to Carbonaceous BOD (Brown & Barnwell, 1987).

Variable	Description	Units	Range	Variable by reach	Temp. Dep.
L	the conc. of ultimate Carb. BOD	mg/l			
K ₁	Carb. deoxygenation rate constant	day ⁻¹	0.02-3.4	Yes	Yes
K ₃	Rate of loss of BOD due to settling	day ⁻¹	-0.36-0.36	Yes	Yes
BOD ₅	5-day BOD	mg/l			
BOD _U	Ultimate BOD	mg/l			
KBOD	BOD conversion rate coefficient	day ⁻¹			

3.2.4.6 Dissolved Oxygen

The oxygen balance in a stream system depends on the capacity of the stream to reaerate itself. This capacity is a function of the advection and diffusion processes occurring within the system and the internal sources and sinks of oxygen. The major source of dissolved oxygen is atmospheric reaeration, as well as the oxygen produced by photosynthesis and the oxygen contained in the incoming flow. The sinks of dissolved oxygen include biochemical oxidation of carbonaceous and nitrogenous organic matter, benthic oxygen demand and the oxygen utilized by algae respiration.

The differential equation solved by QUAL2E to describe the rate of change of oxygen is given in Equation 3.19 and the variable descriptions are given in Table 3.6.

$$\frac{dO}{dt} = K_2(O^* - O) + (\alpha_3\mu - \alpha_4\rho)A - K_1L - K_4/d - \alpha_5\beta_1N_1 - \alpha_6\beta_2N_2 \quad (3.19)$$

Table 3.6 Variable Description Related to Dissolved Oxygen (Brown & Barnwell, 1987).

Variable	Description	Units	Range of values	Variable by reach	Temp. dep.
N_1	the conc. of ammonia nitrogen	mg-N/l			
N_2	the conc. of nitrite nitrogen	mg-N/l			
K_1	Carb. deoxygeneration rate constant	day ⁻¹	0.02-3.4	Yes	Yes
K_2	Reaeration rate constant	day ⁻¹	0.0-100	Yes	Yes
K_4	Benthic oxygen uptake	mgO/ft ² .d	Variable	Yes	Yes
β_1	Rate constant for the biological oxidation of NH ₃ to NO ₂	day ⁻¹	0.10-1.00	Yes	Yes
β_2	Rate constant for the biological oxidation of NO ₂ to NO ₃	day ⁻¹	0.20-2.0	Yes	Yes
α_3	O ₂ production per unit of algal growth	mgO/mgA	1.4-1.8	No	No
α_4	O ₂ uptake per unit of algal respired	mgO/mgA	1.6-2.3	No	No
α_5	O ₂ uptake per unit of NH ₃ oxidation	mgO/mgN	3.0-4.0	No	No
μ	Algal growth rate	day ⁻¹	1.0-3.0	No	No
ρ	Algal respiration rate	day ⁻¹	0.05-0.5	No	No
α_6	O ₂ uptake per unit of NO ₂ oxidation	mgO/mgN	1.0-1.14	No	No
O	The concentration of DO	mg/l			
O*	The saturation conc. of DO at the local temp. and pressure	mg/l			

3.2.4.7 Atmospheric Reaeration Coefficient Estimation

The reaeration coefficient (K_2) is expressed as a function of stream depth and velocity. QUAL2E provides eight options for estimating K_2 values given in following paragraphs. The variables stated in the equations are described in Table 3.7.

Option 1:

This option allows the user to read K_2 values selected by the user.

Option 2: Churchill, Elmore and Buckingham equation

In this equation, the data collected in field measurements of stream reaeration are used.

$$K_2^{20} = 5.026u^{-0.969}d^{-1.673} * 2.31 \quad (3.20)$$

Option 3: O'Connor and Dobbins equation

These equations are based on the turbulence characteristics of a stream.

$$K_2^{20} = \frac{(D_m \bar{u})^{0.5}}{d^{1.50}} \quad (3.21a, 3.21b)$$

$$K_2^{20} = \frac{480D_m^{0.5}S_o^{0.25}}{d^{1.25}} * 2.31$$

Equation 3.21a is for streams displaying low velocities and isotropic conditions whereas the Equation 3.21b is for streams with high velocities and nonisotropic conditions.

Option 4: Owens equation

This equation is based on the monitoring of six streams in England obtained reaeration estimates for shallow, fast moving streams. This equation is used for the streams that have a depth of 0.4-11.0 feet and velocities of 0.1-5.0 ft/sec.

$$K_2^{20} = 9.4u^{-0.67} / d^{1.85} * 2.31 \quad (3.22)$$

Option 5: Thackston and Krenkel equation

This equation is based on the investigation of several rivers in the Tennessee Valley Authority system.

$$K_2^{20} = 10.8(1 + F^{0.5}) \frac{u^*}{d} * 2.31 \quad (3.23)$$

Option 6: Langbien and Durum equation

$$K_2^{20} = 3.3\bar{u} / d^{1.33} * 2.31 \quad (3.24)$$

Option 7:

This option computes the reaeration coefficient from a power function of flow. This empirical relationship is similar to the velocity and depth correlation with flow used in the hydraulics section of QUAL2E:

$$K_2 = aQ^b \quad (3.25)$$

Option 8: Tsivoglou and Wallace equation

This method assumes that the reaeration coefficient for a reach is proportional to the change in elevation of the water surface in the reach and inversely proportional to the flow time through the reach. The equation is:

$$K_2^{20} = c \frac{\Delta h}{t_f} \quad (3.26)$$

Table 3.7 Variable Description Related to Atmospheric Reaeration Coefficients (Brown & Barnwell, 1987).

Variable	Description	Unit
K_2	Reaeration coefficient	day ⁻¹
u	Average velocity in the stream	ft/sec
d	Average depth of the stream	ft
S_0	Slope of the stream bed	ft/ft
F	Froude number	
a	Coefficient of flow for K_2	
b	Exponent on flow for K_2	
c	Escape coefficient	ft ⁻¹
Δh	Change in water surface elevation in reach	ft
t_f	Flow time within reach	ft
D_m	Molecular diffusion coefficient	ft ² /day

3.2.4.8 Dam Reaeration

QUAL2E has the capability of modeling oxygen input to the system from reaeration over dams. The following equation is used to estimate oxygen input from dam reaeration.

$$D_a - D_b = \left[1 - \frac{1}{1 + 0.116abH(1 - 0.034H)(1 + 0.46T)} \right] D_a \quad (3.27)$$

where;

D_a : oxygen deficit above dam, mg/l

D_b : oxygen deficit below dam, mg/l

T : temperature, °C

H : height through which water falls, ft

a : empirical water quality factor (ADAM) (numerical values are given in Table 3.32)

b : empirical dam aeration coefficients (BDAM) (numerical values are given in Table 3.32)

3.2.4.9 Coliforms

Coliforms are used as an indicator of pathogen contamination in surface waters. The expressions for estimating the coliform concentrations are usually first order decay functions, which only take into account coliform die-off. The expression is:

$$\frac{dE}{dt} = -K_s E \quad (3.28)$$

where;

E : concentration of coliforms, colonies/100 ml

K_s : coliform die-off rate, temperature dependent, day⁻¹

3.2.4.10 Arbitrary Nonconservative Constituents

QUAL2E has the capability for modeling an arbitrary nonconservative constituent (ANC). The differential equation describing the interactions for an arbitrary nonconservative constituent is as given in Equation 3.29 and the variable descriptions are given in Table 3.8.

$$\frac{dR}{dt} = -K_6 R - \sigma_6 R + \sigma_7 / d \quad (3.29)$$

Table 3.8 Variable Description Related to Arbitrary Nonconservative Constituent (Brown & Barnwell, 1987).

Variable	Description	Unit	Range	Variable by reach	Temp. dep.
R	Conc. of the NC constituent	mgANC/l			
K_6	ANC decay coefficient	day ⁻¹	Variable	Yes	Yes
σ_6	ANC settling rate	day ⁻¹	Variable	Yes	Yes
σ_7	Benthic source rate for ANC settling rate	mgANC/ft ² .d	Variable	Yes	Yes
d	mean stream depth	ft			

3.2.4.11 Temperature

Temperature is modeled by performing a heat balance on each computational element in the system. The air-water heat balance terms include long and short wave radiation, convection and evaporation using the following equation:

$$H_N = H_{SN} + H_{AN} - H_B - H_C - H_E \quad (3.30)$$

where;

H_N : net heat flux passing the air water surface, BTU/ft².day

H_{SN} : net short wave solar radiation after losses from adsorption and scattering in the atmosphere and by reflection at the interface, BTU/ft².day

H_{AN} : net long wave atmosphere radiation after reflection, BTU/ft².day

H_B : outgoing long wave back radiation, BTU/ft².day

H_C : convective heat flux, BTU/ft².day

H_E : heat loss by evaporation, excluding sensible heat loss, BTU/ft².day

3.3 Data Requirements

The input data in QUAL2E can be grouped into three categories:

- a) A stream/river system,
- b) Global variables,
- c) Forcing functions.

Additionally, there are also three more data groups for simulation control and uncertainty analysis.

In the first step, the complete stream/river system should be described by applying the rules that are defined by the model. The stream system should be divided into reaches that have uniform hydraulic characteristics. Each reach is then subdivided into computational elements of equal length. All reaches must consist of an integer number of computational elements.

The global variables include simulation variables, such as units and simulation type, water quality constituents, and some physical characteristics of the basin.

Forcing functions are user-specified input that drive the system being modeled. These inputs are specified in terms of flow, water quality characteristics and local climatology. The climatological factors are: headwater inputs, point sources or withdrawals, incremental inflow/outflow along a reach and the downstream boundary concentration (optional).

Local climatological data are required for the simulation of algae and temperature. The temperature simulation requires air temperatures, atmospheric pressure, wind velocity and cloud cover. The algal simulation requires values of net solar radiation. For dynamic simulations, these climatological data must be input at regular time intervals over the course of the simulation and are applied uniformly over the river basin.

For modeling steady state temperature and algae, average daily local climatological data are required and may vary spatially over the basin by reach.

The obligatory and the special data for every modeled variable are given in Table 3.9 through Table 3.16.

Table 3.9 Obligatory Data for Each Parameter to be Modeled.

A. Temperature Correction Factors
B. Reach Identification and River/Mile-Kilometer Data
C. Computational Elements Flag Field Data
D. Hydraulics Data
E. Temperature and Local Climatological Data
F. BOD and DO Reaction Rate Constants Data

Table 3.10 Temperature Correction Factors (Rate Coefficients).

BOD Decay	Ammonia Source	Algae Settling
BOD Settling	Nitrite Decay	Coliform Decay
Reaeration	Organic P Decay	Non-conservative Decay
SOD Uptake	Organic P Settling	Non-conservative Settling
Organic N Decay	Dissolved P Source	Non-conservative Source
Organic N Settling	Algae Growth	
Ammonia Decay	Algae Respiration	

Table 3.11 Reach Identification and River/Mile Kilometer Data.

Reach Order or Number
Reach Identification or Name
River Mile/Km. at Head of Reach
River Mile/Km. at End of Reach

Table 3.12 Computational Elements Flag Field Data.

Headwater Source Element
Standard Element, Incremental Inflow/Outflow Only
Element on Mainstream upstream of a Junction
Junction Element
Most Downstream Element
Input Element
Withdrawal Element
Dams

Table 3.13 Hydraulics Data.

Discharge Coefficients	Trapezoidal Channels
Reach Order or Number	Reach Order or Number
Dispersion Constant	Dispersion Constant
a, Coefficient for velocity	Side Slope 1
b, Exponent for velocity	Side Slope 2
c, Coefficient for depth	Bottom Width of Channel
d, Exponent for depth	Channel Slope
Manning "n" for reach	Manning "n" for reach

Table 3.14 Temperature and Local Climatological Data.

Reach Order or Number
Reach Elevation
Dust Attenuation Coefficient
Cloudiness
Dry Bulb Air Temperature
Wet Bulb Air Temperature
Barometric Pressure
Wind Speed

Table 3.15 BOD and DO Reaction Rate Constants Data.

BOD Decay Rate Coefficient
BOD Removal Rate by Settling
Sediment Oxygen Demand
Option for K2
K2 Reaeration Coefficient
a, Coefficient for K2
b, Exponent for K2

3.4 Output Files

There are three types of outputs given by tables. In the output file, these tables are; hydraulics, reaction coefficient and water quality. The hydraulics summary table contains flows, velocities, travel time, depths and cross-sectional areas along each reach. The reaction coefficient table contains the coefficients for simulated constituents. The water quality table contains constituent concentrations along a reach.

Table 3.16 The Variable Input Data Sets.

	DO	BOD	Temp	Algae	N	P	Coliform	ANC	Cons 1,2,3
Global A,N and P parameters				*	*	*			
Flow Augmentation Data	These data are required only if flow augmentation is to be used for each reach.								
N and P Coefficients				*	*	*			
Algae and Other Coefficients				*	*	*	*	*	
Dam Reaeration Coefficients	These group of data is required if oxygen input from reaeration over dams is to be modeled as a component of the DO simulation.								
Initial Conditions									
Temperature	*	*	*	*	*	*	*	*	*
DO	*								
BOD		*							
Cons 1,2,3									*
ANC								*	
Coliform							*		
Chl-a				*					
N cycle					*				
P cycle						*			
Incremental Flow	This group of data accounts for the additional flows into the system not represented by point source inflows or headwaters.								
Inc.Flow	*	*	*	*	*	*	*	*	*
Temperature			*						
DO	*								
BOD		*							
Cons 1,2,3									*
ANC								*	
Coliform							*		
Chl-a				*					
N cycle					*				
P cycle						*			
Headwater Sources Data									
Flow	*	*	*	*	*	*	*	*	*
Temperature			*						

The outputs can be obtained as a data file, graphic or text. It is possible to display or print up to 4 graphs at a time and 3 pollutants for one graph. It can display 2 pollutants with two Y-axes for one graph.

The other feature of the program allows the user to copy the image and paste it to any Windows application, for example Microsoft Word.

3.5. Program Modules

3.5.1 AQUAL2 Module

This is a data preparing program for QUAL2E and QUAL2EU modules. With this module, it is possible to develop a data base for both of these models.

If there is an error in data loading on a screen, then the program gives an error message and does not let the user to continue without correcting it. Execution can not be done. In other words, the program has a self control system in data preparing step.

3.5.2. QUAL2E Module

When the data file is introduced the model, then it can be executed. After executing the program, Q2PLOT module must be run in order to display or print the results of simulation as graphics. If the results are preferred as a tabled output, the output file can be opened in any other Windows applications. In QUAL2E Windows interface, there is another opportunity to copy the image and paste it to any Windows application.

In Windows interface, the QUAL2E model execution is done by clicking on “Run” button.

3.5.3 QUAL2EU Module

Uncertainty analysis for model simulations is assuming a growing importance in the field of water quality management. QUAL2E allows the modeler to perform uncertainty analysis on

steady-state water quality simulations. The uncertainty model prepared for QUAL2E is called QUAL2E-UNCAS.

With QUAL2E-UNCAS, there are three uncertainty analysis techniques:

- a) sensitivity analysis
- b) first order error analysis
- c) Monte Carlo simulation

With this capability, the user can assess the effect of model sensitivities and of uncertain input data on model forecasts. Quantifications of the uncertainty in model forecasts will allow assessment of the risk (probability) of a water quality variable being above or below an acceptable level. The user can select the important input variables to be perturbed and locations on the stream where the uncertainty analysis is to be applied.

The defaults of each technique are different and the results of each one do not fit each other. The difference between each method can be explained with the errors of the approach in first order error analysis or the calculations of variance. The advantage of Monte Carlo simulation is that it gives the frequency distribution of output data. With first order error analysis, it is possible to predict the model sensitivity (Brown & Barnwell, 1987).

Sensitivity Analysis

With sensitivity analysis, it is possible to examine the sensitivity of the model to the variables respectively. It is a method that can examine the sensitivity of a lot of variables at a time and can predict the effects of relationships between the sensitivity of variables to the output variables. On the other hand, it is very difficult to obtain the outputs if a lot of input parameters and variables are selected, because the number of combination groups increases. In this situation, experimental approximations can be used.

With sensitivity analysis option, it is possible to change the input data singly; in groups or with the factorial design methods.

First Order Error Analysis

First order error analysis utilizes the first order approximation for computing variances in multivariate situations. The input variables are assumed to act independently and the model to be linear. The first order approximations to the components of output variance is often good.

In normal applications of first order error analysis, all of the input variables are examined. The module has the capability of constraining the number of input variables to be included in a first order analysis.

Monte Carlo Simulation

Monte Carlo simulation is a method for numerically operating a complex system that has random components input variables are sampled at random from pre-determined probability distributions and the distribution of output values is analyzed statistically. The validity of this method is not affected by non-linearities in the water quality model.

Module assumes that all inputs act independently. Each input is randomized independently from the others. In normal usage, all input variables are randomized in Monte Carlo simulation.

3.5.4 Q2PLOT Module

The graphical representation of the QUAL2E output results is possible by the help of Q2PLOT module. There are two types of graphs: flow vs. distance and pollutant concentrations vs. distance along the river system. The graphics routine has also the capability of drawing the network connections of the river system. The graphics program can be accessed by clicking on the “Graphics” button with the mouse in Windows interface of the QUAL2E (Brown & Barnwell, 1995).

3.6 Data Loading

To create a new data file in QUAL2E Windows interface, there are 24 screens to be represent the data for QUAL2E. The input screen sequences in QUAL2E Windows

Interface are given in Table 3.17. According to these input screens, some auxiliary files are formed and used in the main operation action of the model execution. The flow scheme of the model execution is given in Figure 3.3.

Table 3.17 Input Screen Sequence in QUAL2E Windows Interface (Brown & Barnwell, 1995).

Data Component	Description of input data	Content	Input Screen no.
1	QUAL2E Simulation control	Title, simulation type, unit, time step	1
		Uncertainty analysis, flow augmentation, trapezoidal channels, no. of reaches	
2	Stream system	Reach ID and river km, headwater, comp. element length	2
		Element type for each reach	3
3	Global variables	Water quality (no. of constituents)	4
		Geographical & climatological data	Latitude, longitude, dust attn., elev., evap, coeff.
		Plot DO/BOD	List reach numbers to be plotted
		Observed DO file	7
		Global kinetics, temperature corr. factors	8,9
4	Functional data	Flow	Flow augmentation
			Hydraulic data/local climatology data
		BOD/DO, algae, N, P, reaction coefficients	12,13
			Initial conditions
			Incremental flow
			Headwater
			Point loads/withdrawals
			Dams
			Downstream boundary
5	Clim. data	Global climatological data file	20
6	Uncertainty analysis	Sensitivity analysis, first order error analysis, Monte Carlo simulation	21
		Input conditions, output	
		Input variables for sensitivity analysis	22
		Input variables for first order error analysis	23
		Reach (element) numbers to be printed	24

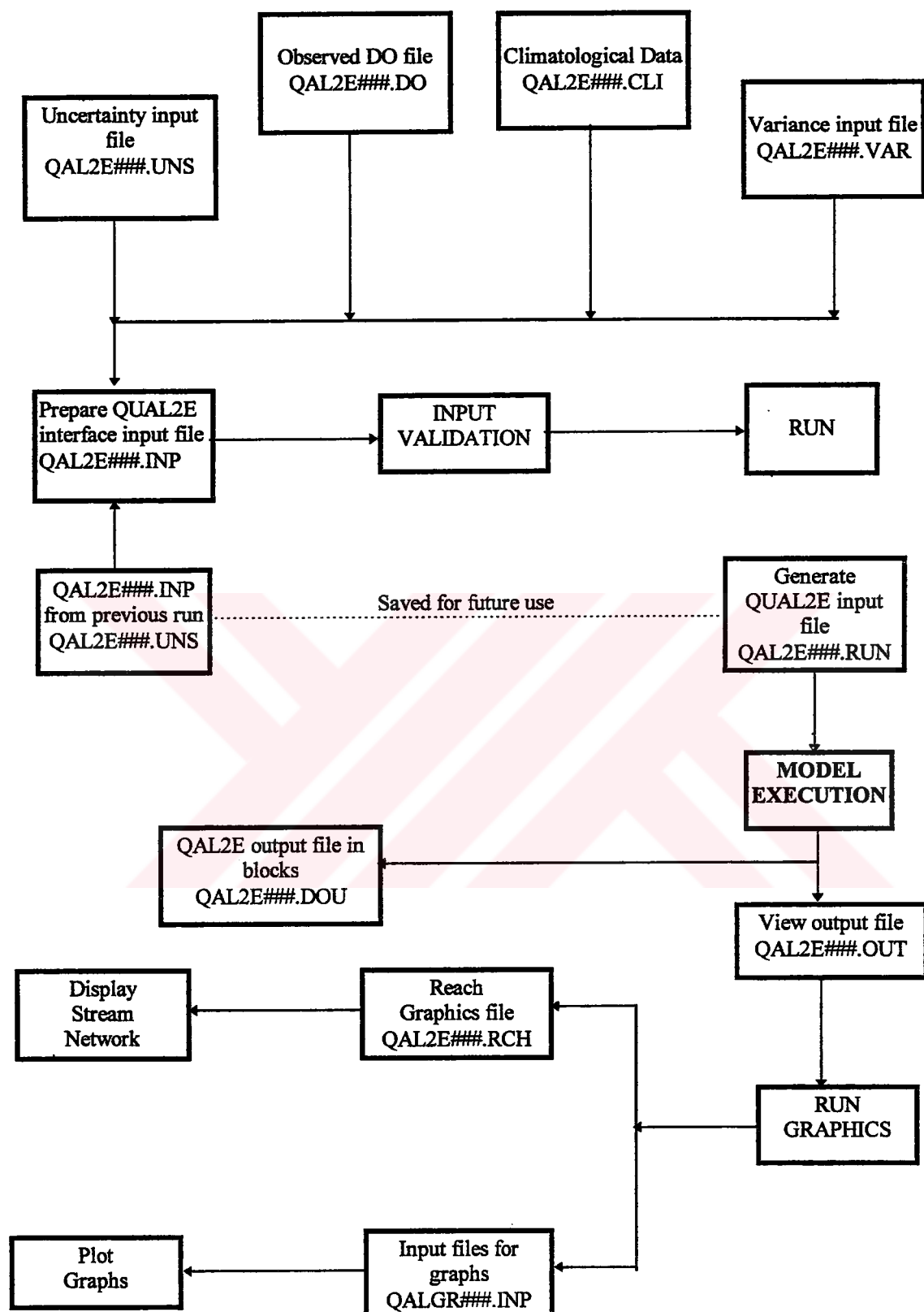


Figure 3.3 Flow scheme of QUAL2E Model Execution (Brown & Barnwell, 1995).

In the first screen - named as “QUAL2E Simulation” - the title of the run, simulation type (steady state-dynamic), units (metric-U.S.), the maximum number of iterations allowed for solution convergence, time step, total simulation length, time increment for RPT2, starting day of simulation and the number of reaches are entered to the computer. The time step interval is used for a dynamic simulation, thus it may be omitted if the simulation is steady-state. In the first screen, if uncertainty analysis and flow augmentation will be done, then those options can be selected. Also if the hydraulic data will be calculated according to trapezoidal channels method, then this option can also be selected. The last data for the first screen is the number of reaches. *Numbering of reaches* starts from the upstream of the river and when a junction comes, the next number is given to the upstream point of the lateral branch of the river (Harmancioğlu, Alpaslan, Özkul, Saner & Fıstıkoğlu, 1993).

In Screen 2, it is possible to display the reach connections. This is possible by reach identification entered by the user. The stream must be described by the reach name, beginning and ending kilometers, whether it is headwater or not, and the computational element length. Once this information has been provided, the interface will automatically link all reaches to a stream system and assign the element types as headwaters, junctions, standards or point loads on Screen 3. The characteristics of each computational element in a reach can be determined in Screen 3 according to the computational elements codes given in Table 3.18.

Table 3.18 Computational Elements Codes.

Element Type	QUAL2E model	QUAL2E Interface
Headwater source element	1	H
Standard element, incremental inflow/outflow only	2	S
Element on mainstream immediately upstream of a junction	3	U
Junction element	4	J
Last element	5	E
Point source element	6	P
Withdrawal element	7	W
Dam		D

A headwater element begins every tributary as well as the main river system, and therefore must always be the first element in a headwater reach. A standard element is one that does not qualify as one of the remaining six element types. An upstream element from a junction is used to designate an element on the mainstream that is just upstream of a junction. A junction element has a tributary entering it. A downstream element is defined as the last element in a stream system. Point sources and withdrawals represent elements that have inputs (waste loads and unsimulated tributaries) and water withdrawals, respectively (Brown & Barnwell, 1995).

Screen 4 is named as “Water Quality Simulation” and used to identify water quality parameters to be simulated. As mentioned in previous sections, QUAL2E can simulate up to 15 water quality constituents in any combination desired by the user. These constituents are;

- a) Dissolved oxygen (DO)
- b) Biochemical oxygen demand (BOD)
- c) Algae as Chlorophyll *a*
- d) Phosphorus cycle (Organic and dissolved)
- e) Nitrogen cycle (Organic, ammonia, nitrite and nitrate)
- f) Coliforms
- g) Arbitrary nonconservative constituent
- h) Three conservative constituents

The model simulates ultimate BOD in the general case. If the user wishes to use 5-day BOD for input and output, the program will internally make the conversion to ultimate BOD. On Screen 4, if only BOD is chosen, the ultimate BOD will be simulated; if both BOD and BOD5 are selected, the 5-day BOD input/output option is applied.

On the fourth screen, it is also possible to determine the specified downstream boundary constituent concentrations if selected.

Geographical and climatological data type are entered on Screen 5. Geographical data includes latitude, longitude, standard meridian of the basin, basin elevation, dust attenuation coefficient and evaporation coefficients. Temperature correction factors could be either the

defaults by the model or user-specified. Climatological data can be varied with reaches or constant throughout reaches depending on the simulation type. If it is a steady-state simulation, this should be entered global for the basin and if it is a dynamic simulation, these data must be entered for each reach. Also, if the user has observed DO data that are stored in a *.DO file, that could be specified under *Observed Dissolved Oxygen* file on Screen 5. The observed data are entered and stored on Screen 7.

On Screen 6, the reach numbers to be plotted and the number of observed dissolved oxygen stations are entered for the mainstream and the tributary.

On Screen 7, the observed dissolved oxygen values are listed. This list includes;

- number of plots
- river location (km)
- minimum DO concentration (mg/l)
- average DO concentration (mg/l)
- maximum DO concentration (mg/l)

If only a single value of DO is available at a given location, it may be entered in either the minimum or average data position. Then by default, model will set the minimum, maximum and average values all equal to the value entered. When more than one plot is specified, the same information must be entered for each plot.

Screen 8 and 9 include the global kinetics and the temperature correction factors. All the parameters and constants shown in Table 3.19 are used for all simulation and represent the kinetics of relationship between algae, nutrient and light. These data are necessary only for algae, nitrogen cycle or phosphorus cycle simulation. For the items on Screen 8 and 9, are detailed in **Appendix A**.

Table 3.19 Global Kinetics Parameters.

Parameter	Range	Average/Default
NH3OXYUP (mgO/mgNH3)	3.0-3.5 (*)	3.43 (*)
NO2OXYUP (mgO/mgNO2)	1.0-1.2 (*)	1.14 (*)
AGYOXYPR (mgO/mgA)	1.4-1.8 (+)	1.60 (+)
AGYOXYUP (mgO/mgA)	1.6-2.3 (+)	2.00 (+)
AGYNCON	0.08-0.09	0.085 (*)
AGYPCON	0.012-0.015	0.014 (*)
AGYGROMX (d ⁻¹)	1.0-3.0 (+)	2.5 (*)
AGYRESPR	0.05-0.5 (*)	0.05 (*)
NHALFSAT (mg/l)	0.01-0.3 0.02-0.4 (*)	0.2 (*)
PHALFSAT (mg/l)	0.001-0.05 0.002-0.1 (*)	0.04 (*)
AGYEXTLN	0.0-0.0088 0.0-0.003 (*)	0.000749 (*)
AGYEXTNL	0.0-0.054 0.0-0.003 (*)	0.0 (*)
LSATCOEF ¹	0.0-0.04 (*)	0.03 (*)
LAVGFACT ¹	0.85-1.0 (+)	0.92 (*)
NUMBDLH ¹	4.0-18.0 (*)	14.0 (*)
TDYSOLAR ¹	0.0-400.0 (*)	350.0 (*)
APREFNH3 ¹	0.1-0.9 (*)	0.9 (*)
A/TFACT ¹	0.0-1.0 0.4-0.5 (*)	0.45 0.44 (*)
NHIBFACT ¹	0.0-10.0 (*)	10.0 (*)

(*) : Program limitations

(+) : Program and literature values coincides

¹ : These data are necessary only for steady-state simulation.

Without any sign : Literature values

On Screen 9, temperature correction factors are stored. If the data are not user specified, the default values are used as theta values. The theta values are given in Table 3. 20.

Table 3.20 Theta Values (Temperature Correction Factors).

Rate Coefficient	Literature Value, d ⁻¹	Default value for the model
BOD Decay	1.047	1.047
BOD Settling	1.024	1.024
Reaeration	1.0159-1.024	1.024
SOD Uptake	1.060 g/ft ² .d	1.060
Organic N Decay	1.047	1.047
Organic N Settling	1.024	1.024
Ammonia Decay	1.047-1.083	1.083
Ammonia Source	1.074 g/ft ² .d	1.074
Nitrite Decay	1.047	1.047
Organic P Decay	1.047	1.047
Organic P Settling	1.024	1.024
Dissolved P Source	1.074 g/ft ² .d	1.074
Algae Growth	1.047	1.047
Algae Respiration	1.047	1.047
Algae Settling	1.024	1.024
Coliform Decay	1.047	1.047
Non-Cons. Decay	1.000	1.000
Non-Cons. Settling	1.024	1.024
Non-Cons. Source	1.000 g/ft ² .d	1.000

On Screen 10, flow augmentation data are entered and stored. This screen is necessary if any flow augmentation is to be used. These data associated with determining flow augmentation requirements and available sources of flow augmentation (Harmancıoğlu et al., 1993). Included items and the model limitations are given in Table 3.21.

Table 3.21 Flow Augmentation Data.

Items	Range	Default
Number of available sources	0.0-100.0	0.0
Minimum DO level (mg/l)	0.0-15.0	5.0
Order of available augmentation sources	0.0-100.0	0.0

Hydraulic and reach variable climatological data can be entered on Screen 11. Two options are available to describe the hydraulic characteristics of the system. One of them utilizes a functional and the other one utilizes a geometric representation. According to the selected option, the data set differs from each other.

Discharge Coefficients

Velocity is calculated as $V=aQ^b$ and depth is calculated by $D=cQ^d$. The values of a, b, c and d for each reach must be defined in this section. These values and the program limitations are given in Table 3.22.

Table 3.22 Discharge Coefficients Data.

Items	Range	Default
Dispersion constant	6-6000	60
a, coefficient for velocity	0-none	0
b, exponent for velocity	0-1	0
c, coefficient for depth	0-none	0
d, exponent for depth	0-1	0
Manning, n, for reach	0.001-0.05	

Trapezoidal Channels

Each reach is represented as a trapezoidal channel. As shown in Table 3.23, these data are used to specify the cross-section, the channel slope and Manning's "n" corresponding to the reach.

Table 3.23 Trapezoidal Channels Data.

Dispersion Constant
Side slope 1
Side slope 2
Bottom Width of Channel
Channel Slope
Manning's "n"

Climatological data supply the global air temperature and climatological information for steady-state water temperature simulation. If model is to be used in the dynamic/diurnal mode, the air temperature and climatological inputs must be reach variable. The reach variable climatological data set is given in Table 3.24.

Table 3.24 Reach Variable Climatological Data.

Items	Range	Default
Reach elevation (m)	-120.0 - 3650.0	305.0
Dust attenuation coefficient	0.01 - 0.15	0.06
Cloudiness	0.0 - 1.0	0.0
Dry bulb air temperature (°C)	2.0 - 55.0	20.0
Wet bulb air temperature (°C)	2.0 - 55.0	15.0
Barometric pressure (mbar)	900.0 - 1100.0	1017.0
Wind speed (m/sec)	0.0 - 36.0	0.0

BOD/DO reaction rate constants, N and P coefficients, and algae and other coefficients data are stored on Screens 12 and 13. This group of data includes reach information on the BOD decay rate coefficient and settling rate, sediment oxygen demand, as well as the method of computing the reaeration coefficient. In this group, the items given in Table 3.25 are set for each reach.

Table 3.25 BOD and DO Reaction Rate Constants Data.

BOD Decay Rate Coefficient (1/day)
BOD Removal Rate by Settling (1/day)
Sediment Oxygen Demand
Type of reaeration
K2 Reaeration Coefficient (for Option 1 only)
a, Coefficient for K_2 (opt.7) or Coefficient for Tsivoglou (opt.8)
b, Exponent for K_2 (opt.7) or Slope of the energy gradient (opt.8)

There are eight types for reaeration coefficient calculation that are listed in Table 3.26. The equations of these types are explained in Section 3.2 briefly.

Table 3.26 Reaeration Options (Brown & Barnwell, 1987).

K₂ Option	Method
1	Read in values of K ₂
2	Churchill
3	O'Connor and Dobbins
4	Owens, Edwards and Gibbs
5	Thackston and Krenkel
6	Langbien and Durum
7	Use equation $K_2=aQ^b$
8	Tsivoglou-Wallace

On Screen 13, the nitrogen, phosphorus and algae coefficients given in Table 3.27 are required if algae, the nitrogen series or the phosphorus series are to be simulated. Otherwise, they may be omitted.

Table 3.27 N and P Coefficients Data.

Items	Literature Values	Model Limitation
Rate coefficient for Organic-N Hydrolysis (1/d)	0.02-2.0	0.0-10.0
Rate coefficient for Organic-N Settling (1/d)	0.001-0.1	0.0-10.0
Rate coefficient for Ammonia Oxidation (1/d)	0.10-1.0	0.0-10.0
Benthos Source Rate for Ammonia (mg/m ² .d)	variable	0.0-none
Rate coefficient for Nitrite Oxidation (1/d)	0.20-2.0	0.0-10.0
Rate coefficient for Organic-P Decay (1/d)	0.01-0.7	0.0-10.0
Rate coefficient for Nitrite Settling (1/d)	0.001-0.1	0.0-none
Benthos Source Rate for Dissolved Phosphorus (mg/m ² .d)	variable	0.0-none

The algae coefficients data are required if algae, the nitrogen series, the phosphorus series, coliform or the arbitrary non-conservative is to be simulated. Otherwise, they may be omitted. This group includes the items given in Table 3.28.

Table 3.28 Algae and Other Coefficients Data.

Items	Literature Values	Model Limitations	Different for each reach	Dependence of Temperature
A	10.0-100.0	1.0-100.0	N	N
B	0.5-6.0	0.0-1.0	Y	Y
C	variable	0.0-3.0	N	N
D	0.05-4.0	0.0-24.0	Y	Y
E	variable	variable	Y	Y
F	variable	variable	Y	Y
G	variable	variable	Y	Y

A: Chl-a/algae Ratio (ug Chl-a/mgA)

B: Algae settling rate (m/d)

C: Non-algal light extinction coefficient (1/m)

D: Coliform decay coefficient (1/d)

E: Arbitrary non-conservative (ANC) mineral decay coefficient (1/d)

F: ANC mineral settling coefficient (1/d)

G: Benthos source rate for ANC (mgANC/m².g)

On Screen 14, the data including initial conditions are entered. This group of data is necessary if dynamic simulation is done. These data establishes the initial conditions of the system, with respect to temperature, dissolved oxygen concentration, BOD concentration and conservative minerals. These data includes the items shown in Table 3.29.

Table 3.29 Initial Conditions Data.

Temperature (°C)	Cons. Mineral 3	Ammonia as N (mg/l)
DO (mg/l)	ANC	Nitrite as N (mg/l)
BOD (mg/l)	Coliform (No/100 ml)	Nitrate as N (mg/l)
Cons. Mineral 1	Chl-a (ug/l)	Organic Phosphorus (mg/l)
Cons. Mineral 2	Organic Nitrogen (mg/l)	Dissolved Phosphorus (mg/l)

Note: Initial conditions for temperature must always be specified whether it is simulated or not. The reasons for this are:

- when temperature is not simulated, the initial condition values are used to set the value of the temperature dependent rate constants;
- for dynamic simulations, the initial condition for temperature and every other quality constituent to be simulated, defines the state of the system of time zero;
- for steady-state simulations for temperature an initial estimate of the temperature between 35°F and 135°F is required to properly initiate the heat balance computations.

Incremental inflow/outflow data are entered on Screen 15. These data account for the additional into the system not represented by point source inflows or headwaters. These inflows, that are assumed to be uniformly distributed over the reach, are basically groundwater inflows and/or distributed surface runoff that can be assumed to be approximately constant through time. Outflows are indicated with a minus "-" sign. The other items are the same with the items in Initial Conditions Data.

On Screen 16, the headwater data are stored. The data set given in Table 3.30 must be arranged for each headwater starting from the most upstream part of the river for the modeled parameter.

Table 3.30 Headwater Data.

Headwater Identification	Coliform (No/100ml)
Flow (m ³ /sec)	Chl-a (ug/l)
Temperature (°C)	Organic Nitrogen (mg/l)
DO concentration (mg/l)	Ammonia Nitrogen (mg/l)
BOD concentration (mg/l)	Nitrite Nitrogen (mg/l)
Conservative Mineral 1 (mg/l)	Nitrate Nitrogen (mg/l)
Conservative Mineral 2 (mg/l)	Organic Phosphorus (mg/l)
Conservative Mineral 3 (mg/l)	Dissolved Phosphorus (mg/l)
ANC	

Screen 17 stores the data including point loads and withdrawals whereas the dams data are stored on Screen 18.

On Screen 17, point source inputs and point withdrawals from the stream system are specified. Point sources include both waste loads and unsimulated tributary inflows. This group includes the same items with initial conditions including with point load identification, percent treatment and point load inflow or withdrawal. (a withdrawal must have a minus "-" sign.)

On Screen 18, the dam reaeration coefficients are required if oxygen input from reaeration over dams is to be modeled as a component of the dissolved oxygen simulation.

Dam reaeration effects are estimated from the empirical equation. In this program, “dam” term is used for a small scaled water collecting systems. The included items are shown in Tables 3.31 and 3.32.

Table 3.31 Dam Reaeration Coefficients Data.

Dam order or number	BDAM coefficient
Reach number of dam	Percent of flow over dam
Element number of below dam	Height of dam
ADAM coefficient	

Table 3.32 ADAM and BDAM Coefficients.

Situation	ADAM Coefficient
Clean water	1.80
Slightly polluted water	1.60
Moderately polluted water	1.00
Grossly polluted water	0.65
	BDAM Coefficient
Flat broad crested weir	0.70-0.90
Sharp crested weir with straight slope face	1.05
Sharp crested weir with vertical face	0.80
Sluice gates with submerged discharge	0.05

On Screen 19, the user can store the downstream boundary data. This feature of model is useful in modeling systems with large dispersion in the lower reaches. When downstream boundary concentrations are supplied, the solution generated by model will be constrained by this boundary condition. If the concentrations are not provided, the constituent concentrations in the most downstream element will be computed in the normal fashion using the zero gradient assumption. The items that are included to this group are the same with initial conditions' items (Brown & Barnwell, 1987).

On Screen 20, the global climatological data can be entered and stored in *.CLI file. This group of data includes the simulation month, day, year and hour, solar radiation, cloudiness, dry and wet bulb air temperature, barometric pressure and wind speed. These values are entered constant for the basin (Brown & Barnwell, 1995).

3.6.1. Uncertainty Data Loading

On Screens through 21 to 24, the uncertainty analysis data can be stored. Uncertainty analysis includes three techniques; sensitivity analysis, first order error analysis and Monte Carlo simulation.

Screen 21 includes the description of uncertainty analysis, type of analysis - sensitivity analysis, first order error analysis or Monte Carlo simulation -, magnitude of input perturbation (%) and the number of simulations. Input conditions are the other item of Screen 21. There are four options for this item:

- a) Single / multiple perturbation
- b) level factorial design
- c) All inputs
- d) Generic inputs

If the "single" option is selected, then it determines the input variables, that are to be analyzed, as a group (multiple) or singly (single). If "2-level" option is selected, then the variable number (maximum of 3) must be entered.

The other items are; flow and quality parameters, input variance file, intermediate output - no output summary, complete output summary or partial output summary. After entering all these items, then the type of output variable group must be selected. There are 3 types;

- (a) Hydraulic - flow, height, velocity, dispersion, etc.
- (b) Quality - the selected constituents in QUAL2E.
- (c) Internal - algae, nutrient, light, etc.

Then the number of locations (maximum of 5) where the sensitivity analysis will be done in the basin and in another screen, the number of sensitivity analysis runs must be entered. Then for each analysis, the type of input variable must be selected:

- (a) Single - one variable sensitivity analysis
- (b) Multiple - Multivariate sensitivity analysis
- (c) Factorial - Factorial design option

On the next screen - Screen 22 - input variables for sensitivity analysis given in Table 3.33 and on Screen 23, the input variables for first order error analysis and Monte Carlo simulation given in Table 3.34 are stored (Brown & Barnwell, 1995).

Table 3.33 Input Variables for Sensitivity Analysis.

Type of input
Number of input variable
Input perturbation

Table 3.34 Input Variables for First Order Error Analysis and Monte Carlo Simulation.

Variable name
Generic group
Coefficient variation
Probability

Finally, on Screen 24, the user can select the element numbers to be printed.

3.7 Model Limitations and Default Values

QUAL2E has been designed to be a relatively general program; however, certain dimensional limitations were imposed during program development (Brown & Barnwell, 1995). These limitations are;

- Reaches: a maximum of 50
- Computational elements: no more than 20 per each reach or a total of 500
- Headwater elements: a maximum of 10
- Junction elements: a maximum of 9
- Point source and withdrawal elements: a maximum of 50

There are also limitations in the system requirements in order to run the model under Microsoft Windows. The minimum system requirements are as below (Brown & Barnwell, 1995):

- Windows version 3.1.
- 80386 processor
- 4 megabytes RAM
- 10 megabytes hard disk space

Note: A math co-processor is recommended but not required.

On the other hand, each model parameter has a literature range for computing and there is a range of the model itself. In some cases, these values do not fit to each other. In this case, model computes the parameters or variables according to the its own range.

The minimum, maximum and default values of the parameters according to the model are given in **Appendix B**.

3.8 Basin Identification

In order to model river water quality with the QUAL2E program, the river system must first be defined hydrodynamically in terms of slope, roughness, flow and cross-sectional properties. As a second step, the quality properties of the river are defined according to parameter concentrations and discharge locations. In other words, the first phase of modeling is to collect data on the river basin and prepare the data set necessary for the model.

After defining the basin with site studies, the points where the hydrologic characteristics change must be marked on the map of the basin. Then, according to these data, the river is divided into parts, called reaches, that have uniform hydrologic properties. Each reach is further divided into computational elements, and the number of computational elements are determined. The length of a computational element is constant for each reach and consequently the reach length must be the multiple of the computational element length. In addition, the starting and finishing kilometers of each reach must be determined. As a second step, point loads (domestic or industrial wastewater discharge etc.) or withdrawals (drinking water etc.) and surface flows (storm water, groundwater, infiltration etc.) must be determined in terms of both the flowrates and their locations.

In defining the basin on the model, the main problem is to transfer the physical properties of the basin to the computer correctly. These properties are the locations and the identifying numbers of headwaters, junctions, point loads or withdrawals, the numbers and the starting and finishing kilometers of the reaches (Harmancıoğlu et al., 1993).

After this step, the hydraulic and quality properties of river must be recorded to the computer. In this step, all point loads, withdrawals, surface flow and the hydraulic and quality data of the upstream point must be entered. In order to run the model, all the preparations must be done. After all these preparations, the QUAL2E model can be run.

In order to run the QUAL2EU - the uncertainty analysis module -, uncertainty analysis data must be prepared.

After obtaining the output files either from QUAL2E or from QUAL2EU, Q2PLOT graphic program module can be used to observe the results. With this module, graphics can be displayed on screen or can be printed.



CHAPTER FOUR

SELECTED RIVER BASIN

4.1 Introduction to the Basin

Gediz River Basin is located in West Anatolia between the Aegean Sea and Küçük Menderes and Bakırçay river basins. The basin is the largest in the Aegean region, covering 2.3% of the total surface area of Turkey (Gündoğdu, 1991). The Gediz river is selected for purposes of this study since the basin needs sound water quality management practices due to the increasing problem of water pollution.

The basin is covered with mountains of 2000 m. high from the north, south and the east, and it reaches the Aegean Sea from the west. The length of the river is 276 km., and the main tributaries are Deliiniş stream, Selendi stream, Demirci stream, Nif stream, Alaşehir stream and Kumçay. The drainage area of the river is 16 775 km².

The basin has a geographical structure dominated by mountains extending perpendicular to the Aegean shores and the grassy plains between these mountains. The sediment carried from upper basins to the grassy plains are filling the river bed and causing floods by bank overflows. Thus, floods threaten the agricultural and residential areas very frequently.

Adala, Ahmetli, Menemen, Akhisar, Selendi, Kapaklı and Alaşehir plains make up the lower Gediz plains. In the upper basin, there are little plains along the river valley. Near the Gediz village, the valley expands and forms the Gediz plain.

The main water resources of the basin are the main stream of the Gediz river, and the tributaries of Alaşehir and Gördes streams. The main lakes are Marmara Lake and the Demirköprü Dam Reservoir.

4.1.1 Geology

Gediz valley is one of the greatest alluvium beds of West Anatolia. The mountains on the north and south of the valley where Salihli, Alaşehir and Sarıgöl are located, are formed of metamorphite and have a height of 2000 m. The highest mountain is Bozdağ with a height of 2169 m. This mountain is between the Küçük Menderes and Gediz valleys.

Ash fans and new lava surfaces can be observed between Kula and the Demirköprü Dam. The Gediz River reaches the valley from the north of Salihli. The direction of this valley is approximately east-west.

There are a lot of faults between the Gediz valley and the mountains around it. The formation of the valley can be explained by these faults.

4.1.2 Climate

The basin is in the typical Mediterranean climate - summers are hot and dry; winters are warm and rainy. January and February are the most rainy months whereas July and August are the driest months. The annual average temperature is 15.6°C.

The annual average rain in the basin is 635 mm, annual total minimum rain 327 mm, and the maximum rain is 1116 mm. The 25% of the annual total rain falls in the April - October period whereas 75% of it occurs in the November - March period. While the average water need of plants is 900 mm, the effective part of the annual rain is approximately 170 mm.

4.1.3 Population

In the basin, there is one large city, Manisa, with 12 towns together with a few towns in the İzmir area. The populations of these residential areas are given in Table 4.1 for the year 1990.

The state highways passing through the basin are İzmir-Manisa-Balıkesir, Manisa-Salihli-Simav-Kütahya and Salihli-Kula-Uşak. Besides this, there are two railways; İzmir-Manisa-Balıkesir and İzmir-Manisa-Alaşehir-Uşak. There are also two airports, one in İzmir and one in Akhisar.

Table 4.1 Population of Residential Areas in the Gediz Basin (as of 1990).

	Population of towns (capita)	Population of villages (capita)	Total
İZMİR			
Foça	12057	13165	25222
Karşıyaka	418724	5472	424196
Kemalpaşa	16354	39721	56075
Menemen	29006	47037	76043
MANİSA			
City town	158928	62766	221694
Ahmetli	10190	9364	19554
Akhisar	73944	78453	152397
Alaşehir	36649	54713	91362
Demirci	20576	39608	60184
Gölmarmara	10976	5753	16729
Gördes	9767	29086	38853
Köprübaşı	5816	10031	15847
Kula	17208	30924	48132
Salihli	70861	61874	132735
Sarıgöl	10677	24005	34682
Saruhanlı	12977	60911	73888
Selendi	6773	18642	25415
Turgutlu	73634	27063	100697

4.1.4 Water and Land Resources

4.1.4.1 Water Resources

As noted earlier, the main tributaries are the main stream of Gediz river and Alaşehir and Gördes streams. According to 1992 data, the annual average flow of the river is 1950 hm³ which makes up 1.2% of the water potential of Turkey. The annual average potential is 360 lt/s/hm² and the ratio of runoff to precipitation is 26%.

The major structures that supply water for irrigation in the basin are Demirköprü Dam and the Marmara Lake. Basic characteristics of these reservoirs are given in Tables 4.2 and 4.3. The basic irrigation schemes are: Adala (24 875 ha), Ahmetli (54 850 ha), Menemen (28 030 ha). The total area irrigated is 107 755 ha. For these irrigations, 546.24 hm³ water from Demirköprü dam and 108.56 hm³ water from Marmara lake are used annually.

Table 4.2 Characteristics of the Demirköprü Dam and Reservoir.

Drainage area	6590 km ²
Annual average inflow	844 hm ³ / year (1962-1989)
Regulation rate	89%
Type	Rock and sand gangue
Height (From the thalweg)	74 m
Height (From the base)	77 m
Total embankment volume	4.6 hm ³
Active volume	814 hm ³
Total reservoir volume	1105 hm ³

Table 4.3 Characteristics of the Marmara Lake.

Drainage area	1780 km ²
Annual average inflow	193 hm ³ /year (1980-1990)
Type	Natural lake
Height (From the thalweg)	5.6 m
Height (From the base)	5.6 m
Active volume	290 hm ³
Total reservoir volume	320 hm ³

The basin has a number of springs called Göksu, Göldeğirmeni, Sarıkız, Beşgöz, and Akpınar springs. The groundwater in Menemen, Turgutlu, and Salıhlı plains is used for industrial water supply.

The safe groundwater reserve in the basin is 539 hm³/year. The annual potential of groundwater and springs in the basin are given in Table 4.4.

Table 4.4 The Groundwater Potential of the Gediz Basin.

Source	Annual potential
Göksu springs	63
Sarıköz springs	54
Beşgöz springs	30
Akpınar springs	33
Turgutlu springs	40
Salihli plain	15
Total	235

4.1.4.2 Land Sources

The soil structure in the basin is generally granular, consisting of sand and clay.

The depth of the soil is suitable for the growing of deep rooted plants. In the profiles, stone and gravel layers can be found very often. The permeability of the soil is generally good; parts with a great amount of sodium and heavy structured clay soil have a permeability of 0.50 cm/h.

The muddy soil has a pH of neutral and nearly neutral. At places where it contains a great amount of sodium and lime, pH is above 8. Areas that can not be washed by storm waters are rich of lime. It is stated that places which have bad drainage and little topographical slope show a problem of salinity. Drainage problems are significant in areas close to the river and the sea.

4.1.5 Economy

The major economical activity in the basin is agriculture, and the main products are cotton, vegetable, grapes and cereals.

There are thread and weaving factories in Salihli; wool factory in Kula; and textile factories in Manisa. There are also salt establishments in Çamaltı. Furthermore, there are small factories and manufacturing facilities to process agricultural products almost in every village center. Handicrafts such as carpet-weaving are also characteristic.

There are several mines in the basin, including mica, lignite, marble, chromium, and graphite. However, most of these mines are not processed.

The main trade in the basin relies on agricultural products. The major trade centers are Manisa, Akhisar and Salihli. The trade harbor of the basin is the İzmir harbor.

4.2 Water Potential (Quantity) of the Gediz River Basin

4.2.1 The Main River

According to measurements taken at the Selendi streamgaging station, the maximum flow of the Gediz stream is $773 \text{ m}^3/\text{s}$ and the minimum is $2.35 \text{ m}^3/\text{s}$. The measurements of Manisa station show that these values range from $482 \text{ m}^3/\text{s}$ to $14.6 \text{ m}^3/\text{s}$. The difference between these measurements is due to the storage at Demirköprü which is located between the two streamgaging stations. The average flowrates are $25.4 \text{ m}^3/\text{s}$ in Selendi and $107.5 \text{ m}^3/\text{s}$ in Manisa (Manisa Valiliği Çevre İl Md., 1995).

All the domestic wastewaters of Manisa are conveyed by DSI (State Hydraulic Works) channels to the Manisa domestic treatment plant, from where they are discharged to Gediz river. Medar stream the from north carries the domestic wastewaters of Akhisar village to Gediz river. The wastewaters of Manisa Organized Industry constitute a significant source of pollution in the basin. They are discharged to the Gediz river after treatment at the District's treatment plant.

Another pollution source is the Nif stream that carries the domestic and industrial wastewaters of Kemalpaşa to the river. Other sources are the domestic wastewaters of Menemen, Muradiye, Salihli, Demirci, Ahmetli, Turguthu, Alaşehir, Sarıgöl and Saruhanlı that are also discharged to the Gediz river. The pollution in the river has increased rapidly since 1980 and led to the death of 1 ton of fish in 29.04.1989 (Manisa Valiliği Çevre İl Md., 1995). It was determined at these dates that the quality of the Gediz river had been in the 4th category (very polluted water) with respect to pollution levels dictated by phenolic matter and cyanide. Gediz river is also significantly polluted by leather industry and carries substantial amounts of boron (B).

4.2.2 Tributaries of the Gediz River

Alaşehir stream rises from the north of Koparan and Karagöz villages. The length of the stream is 115 km and the drainage area is 2680 km^2 . According to measurements of DSI, the average of flow in the stream is $15.7 \text{ m}^3/\text{s}$ (total of $494 \text{ m}^3/\text{year}$). The river bed of is made of very

fine materials that can be eroded away easily. The stream dries 8 months a year; yet it becomes a great danger for the Alaşehir plain during the rainy season.

The Selendi stream rises from the southern part of Salhane and Derbent mountains near Simav, and its total drainage area is 702 km². It joins the Gediz river near Tahtacı village. According to observations at Derköy, the average flowrate is 4.5 m³/s (total of 143 million m³/year).

The Deliiniş stream originates from the southern parts of Simav mountains and flows in the south direction. It joins the Gediz river near Borlu village. The drainage area of this tributary is 827 km², and the average flow is 6.4 m³/s (total of 201 million m³/year).

The Demirci stream rises from the southern parts of Demirci mountains to join the Gediz river at the eastern part of Adala. It has an average flow of 8.1 m³/s (total of 254 million m³/year).

The Sarmaşık stream rises from the southern part of Demirci mountains and takes the name of Gördes after the confluence with the Medar stream. The length of the stream is approximately 90 km and the total drainage area is 1560 km².

The Nif stream, that originates near Ulucak village, passes through Kemalpaşa plains and joins the Gediz river. It is fed by a little stream that rises from Nif mountain and dries in summer. The drainage area is 1087 km². This region has a great potential for agriculture with sufficient surface and groundwater resources. However with the industrialization of the Kemalpaşa area, groundwater became polluted and the Nif stream has become a natural sewage canal due to the discharges of several types of industrial wastewaters. 112 industrial sources discharge their wastewaters to the Nif stream. These industries include heavy industry, textile, chemistry, paint, marble, leather, drinks, paper, cardboard, enamel and metal industries. It is determined that the Nif stream is highly polluted with respect to organic matter, nitrogen, phosphorus, and phenol from industries. Cyanide pollution has also reached significant levels.

4.2.3 Streamflow Observations

State Hydraulic Works (DSI) and Electrical Works (EİE) have observed runoff on the Gediz river and its tributaries since 1951. The locations of the current streamgaging stations are shown in Figure 4.1 and the average flowrates at each station are given in Table 4.5. The set of water flow data used in the study are given in Appendix C.

Table 4.5 Streamgaging Stations in the Gediz River Basin.

Station	Agency	Annual averages m ³ /s	Seasonal Averages m ³ /s			
			Winter	Autumn	Summer	Spring
Medar Çayı - Kayahoglu (509)	EIE	1.466	3.040	0.651	0.649	2.356
Kum Çayı - Kiliik (510)	EIE	3.523	9.035	3.008	2.283	4.907
Selendi Çayı - Dereköy (514)	EIE	1.336	2.220	0.467	1.685	2.371
Delinış Deresi - Topuzdamları (515)	EIE	1.505	2.705	0.718	0.535	2.824
Gediz Nehri - Manisa (518)	EIE	33.651	55.120	44.810	13.290	36.740
Demirci Çayı - Borlu Köprüstü (522)	EIE	1.486	3.134	0.357	0.765	2.993
Gediz Nehri - Acısu (523)	EIE	7.503	12.650	7.335	7.419	14.390
Murat Çayı - Sazköy (524)	EIE	1.371	1.288	0.913	1.744	3.420
Yığıtler Deresi - Yığıtler (525)	EIE	0.802	2.702	0.224	0.072	1.319
Alaşehir Çayı - Baklacı (526)	EIE	1.029	1.301	0.762	0.908	2.099
Gördes Çayı - Darıbükü (527)	EIE	2.553	7.941	0.712	0.993	4.996
Alaşehir Çayı -Baklacı (001)	DSI	361.628	1060.000	20.000	355.000	2120.000
Gediz Nehri-Urganlı (002)	DSI	15.860	18.500	5.600	18.000	32.000
Kum Çayı-Kiliik (003)	DSI	1310.583	7860.000	1350.000	268.000	3250.000
Medar Çayı-Medar Köprüstü (004)	DSI	2.128	3.800	0.000	0.000	0.900
Gediz Nehri-Muradiye Köprüstü (005)	DSI	183.250	72.000	14.500	23.500	85.000
Gediz Nehri-Menemen Köprüstü (006)	DSI	39.514	72.000	14.500	23.500	85.000

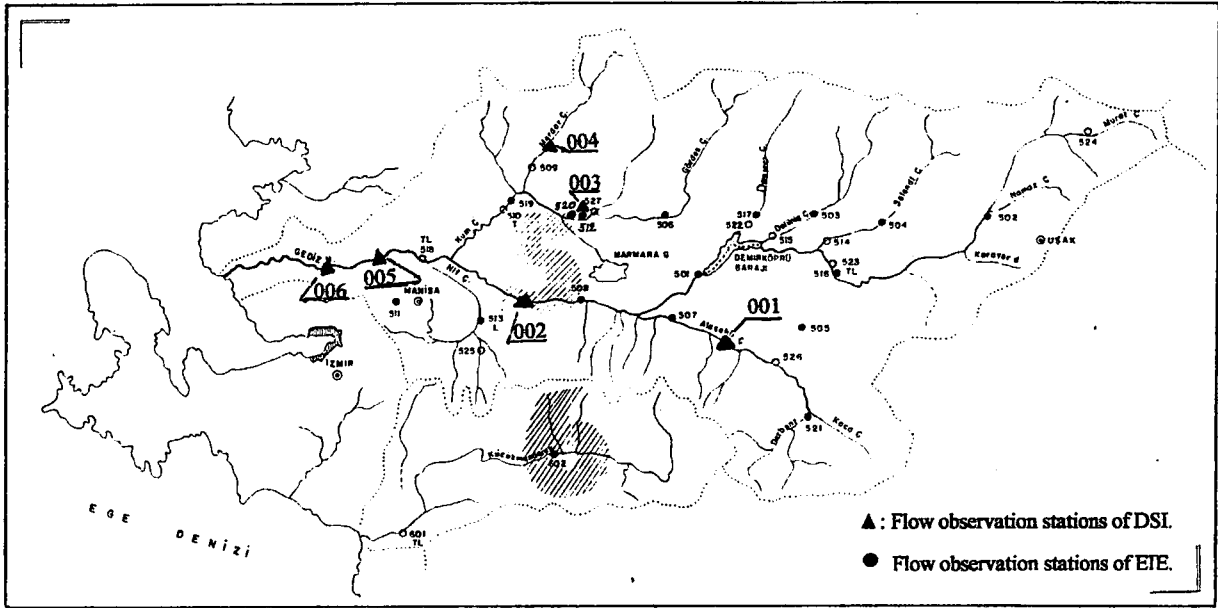


Figure 4.1 Flow Observation Stations of EIE and DSI.

4.3 Water Quality of the Gediz River Basin

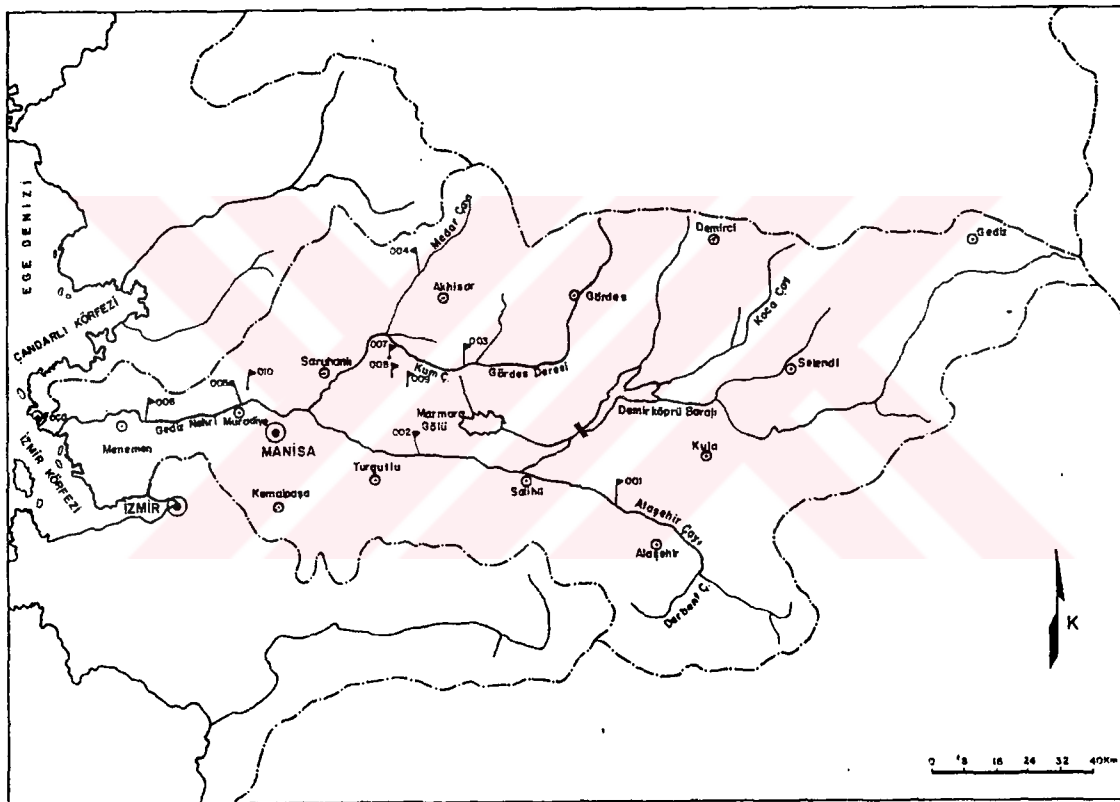
4.3.1 The Water Quality Observations

Water quality in the Gediz river has been observed by DSI at a number of sites since 1980. These observations started at 6 locations which still continue to operate (with the exception of Baklacı station). In recent years, the number of sampling sites was increased to above 40 for purposes of specific surveys. At present, most of these stations are discontinued, so that the original 6 stations, listed in Table 4.6, have the longest period of observations. Water quality observations of these stations are used in the present study. At these sites; the parameters that are observed include temperature, pH, electrical conductivity, total dissolved solids, suspended solids, total solids, turbidity, M-Al, P-Al, Cl, organic nitrogen, $\text{NH}_3\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, dissolved oxygen, pV, biochemical oxygen demand, TH, dissolved phosphorus, SO_4 , Fe, Mn, Na, K, Ca, Mg, chemical oxygen demand, TKN, phenol, oil, boron, TBI and BMWP.

In the study presented, modeling is carried on DO, BOD, N and P cycle, SS and EC variables. The set of water quality data used in the study are given in **Appendix D**.

Table 4.6 Water Quality Sampling Sites Along the Gediz River.

Station
Alaşehir Çayı- Baklacı (001)
Gediz Nehri - Urganlı (002)
Kum Çayı - Kılık (003)
Medar Çayı - Medar Köprüsü (004)
Gediz Nehri - Muradiye Köprüsü (005)
Gediz Nehri - Menemen Köprüsü (006)

**Figure 4.2 The Water Quality Observation Stations of DSI.**

4.3.2 Current Status of Water Quality in the Basin

The State Hydraulic Works (DSI) observes approximately 35 variables in Gediz. With these collected data, DSI has evaluated the river water quality according to the standard quality classes given in "*Water Pollution Control Regulations - Table 1*". This table is given in **Appendix E**.

The general situation of the basin shows that: NO₂-N and pH from Group A; BOD, COD and TKN from Group B and Hg, Pb and B from Group C are the characteristic variables of water quality in their group.

In general, NO₂-N and TKN originate from agricultural and domestic, BOD from domestic, COD, Hg, and Pb from industrial sources. B originates from geothermal waste; and pH from high bacteriological activities.

The current basin-wide situation of the water quality in the Gediz river basin can be summarized as in Tables 4.7 and 4.8.

Table 4.7 River Water Quality Classes Determined by Bacteriological Parameters.

Region	Quality Classification					
	Group A			Group B		Group C
	NH3-N	NO3-N	NO2-N	COD	TKN	B
Except Nif stream	1st class		3rd or 4th class			
At the discharge points of wastewaters				3rd - 4th class		
Throughout the river						Rather effective in river water quality

Table 4.8 River Water Quality Classes Determined According to Physical and Inorganic Chemical Parameters, Organic Parameters and Inorganic Pollution Parameters

Streams	Quality Classification		
	A	B	C
On Deliniş - Selendi streams		1st class	
On Demirci - Gediz streams		4th class	
Throughout the whole river			Hg, Pb, B are in very high conc.
Demirköprü dam lake exit	No change in conc. of pH, NO ₂ -N	Improvement in conc. according to the entrance of dam lake.	
Before Alaşehir and Gediz junction	No change in concentration	BOD - 3rd class	Boron - 4th class
In the upstream of Alaşehir stream	4th class in all parameter groups; this is due to agricultural activities, fertilizer and pesticides and domestic wastewater discharge		
After Alaşehir stream junction	NO ₂ -N - 3rd class		Boron - 4th class
Near Turgutlu region		Negative change in BOD. COD - 3rd class	
On Gördes stream	All of them are in 3rd class. This is to the domestic wastewater discharge of Gördes village, carpet-weaving and mine beds		
On Medar stream	pH - 3rd class	Domestic wastewater - 2nd class	
After junction of Medar and Gördes streams	4th class	3rd class	4th class
On Nif stream	NO ₂ -N - 3rd class		2nd class
After Kemalpaşa	All of them are in 4th class. This is due to industrial and domestic wastewaters.		
After Nif junction		4th class	
Before sea		3rd class	

CHAPTER FIVE

CASE STUDY

5.1 General

The QUAL2E model is applied to the case of the Gediz river basin as steady-state simulation using annual and seasonal values of simulated variables. The annual and seasonal values of the basic quality variables are obtained from DSI annuals (DSI, 1987) as shown in Appendix D. The first step in model application is to divide the river system into reaches. Considering the hydraulic characteristics, cross-sectional areas and the location of gaging stations, the river is divided into 13 reaches as indicated on Fig. 5.1.

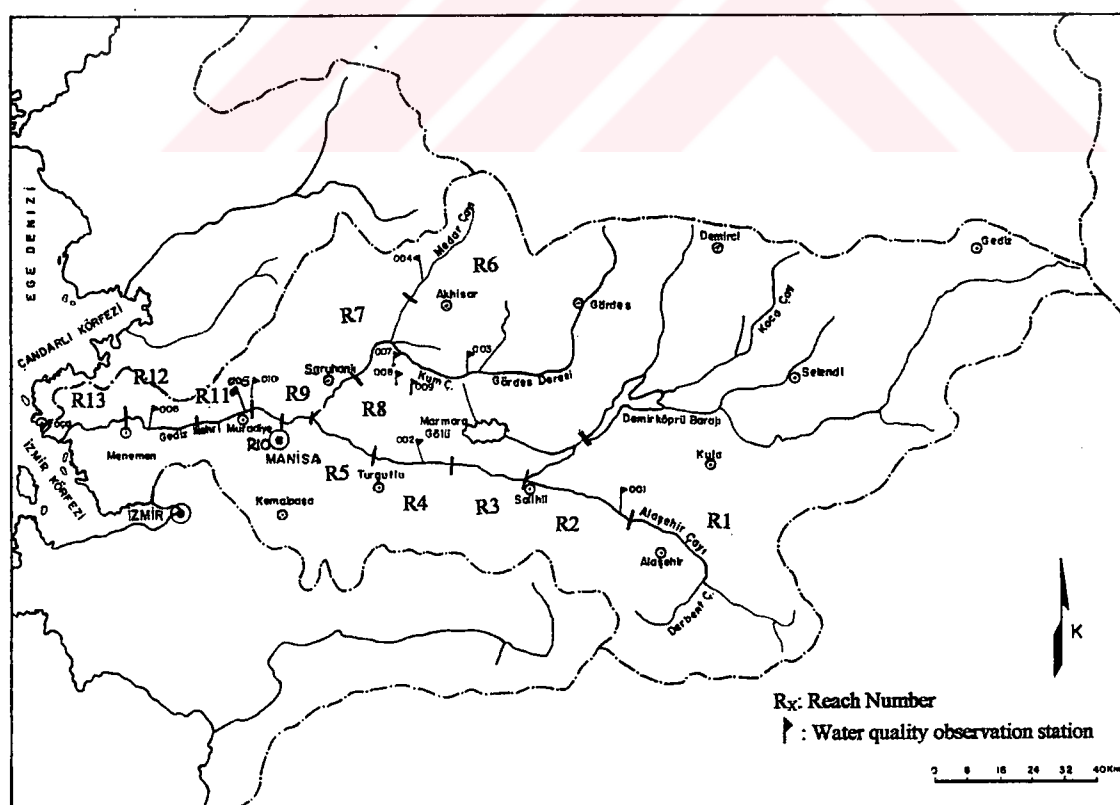


Figure 5.1 The River Reaches.

The initial step in the application is preparation and entering of relevant data using the AQUAL module. Next, the simulation runs are realized through the QUAL2E program module. The outputs are obtained in the form of water quality plots versus distance to show both the annual and seasonal variations of water quality along the river.

5.2 Preparation of the Input Data

After numbering of reaches, the “QUAL2E Simulation” data - the first screen on data loading - are entered. These simulation data are given in Table 5.1.

Table 5.1 “QUAL2E Simulation” Data Set.

Description of the run: Gediz River Basin	
Simulation Type	Units
☒ Steady State	O U.S. units
☐ Dynamic	☒ Metric
☐ Uncertainty analysis ☐ Flow augmentation ☐ Trapezoidal channels	
Maximum iterations	130
Time step	1
Starting day of simulation	180
Total simulation length	30
Time increment	1
Number of reaches 13	

Among these data, the items “*maximum iterations*” and “*starting day of simulation*” should be determined for steady-state simulation, whereas *time step*, *starting day of simulation*, *total simulation length* and *time increment* are needed for dynamic simulation.

For the second data set, the reach connections are determined. As noted earlier, the selected river system is divided into reaches and computational elements in order to identify the system on the computer. The river is divided into 13 reaches. It has two headwaters (Alaşehir and Akhisar). By selecting the computational element length, Δx , as 1.5 km, each reach is divided into computational elements.

Another requirement for identifying the river system on the computer is to set the headwater and end location kilometers. These data are specified as in Table 5.2.

Table 5.2 “Stream system” Data Set.

Reach No	Reach Name	Beginning of reach (km)	End of reach (km)	Headwater element	Δx (km)
1.0	Alaşehir-Salihli	219.0	192.0	*	1.5
2.0	Salihli-Demirköprü	192.0	165.0		1.5
3.0	Demirköprü-Ahmetli	165.0	139.5		1.5
4.0	Ahmetli-Urganlı	139.5	115.5		1.5
5.0	Urganlı-Turgutlu	115.5	91.5		1.5
6.0	Akhisar-Saruhanlı	57.0	46.5	*	1.5
7.0	Saruhanlı-Kumçay	46.5	22.5		1.5
8.0	Kumçay-Turgutlu	22.5	0.0		1.5
9.0	Turgutlu-Manisa	91.5	72.0		1.5
10.0	Manisa-Gediz	72.0	52.5		1.5
11.0	Gediz-Muradiye	52.5	33.0		1.5
12.0	Muradiye-Menemen	33.0	16.5		1.5
13.0	Menemen-Sea	16.5	0.0		1.5

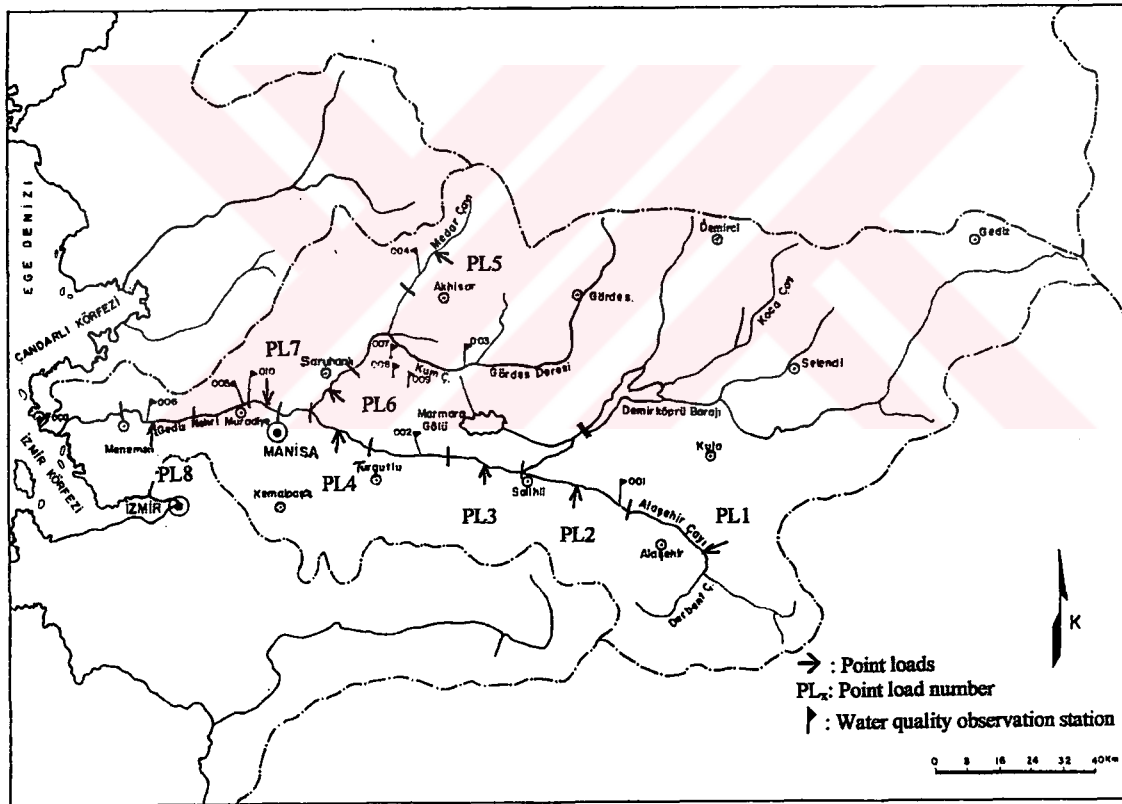
On Screen 3, the element types are determined as explained in Section 3.6 and in Table 3.18. The computational element identification is given in Table 5.3. In order to specify the computational element types, the point load identifications must also be determined. The point loads identification data are set as given in Table 5.4 with their reach numbers and kilometers. Figure 5.2 shows the locations of domestic wastewater discharges along the river.

Table 5.3 “Computational elements type” Data Set.

Reach No	Com. el. no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	18	H	S	S	S	S	S	S	S	S	S	S	S	P	S	S	S	S	S
2	18	S	S	S	S	S	S	S	S	S	S	S	P	S	S	S	S	S	S
3	17	S	S	S	S	S	S	S	S	S	P	S	S	S	S	S	S	S	
4	16	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
5	16	S	S	S	S	S	S	S	S	S	S	S	S	S	P	S	U		
6	7	H	S	S	S	S	P	S											
7	16	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		
8	15	S	S	S	S	P	S	S	S	S	S	S	S	S	S	S			
9	13	J	S	S	S	S	S	S	S	S	S	S	S	S					
10	13	S	S	S	S	S	S	S	P	S	S	S	S	S					
11	13	S	S	S	S	S	S	S	S	S	S	S	S	S					
12	11	S	S	S	S	P	S	S	S	S	S	S							
13	11	S	S	S	S	S	S	S	S	S	S	E							

Table 5.4 Point Load Identification Data Set.

Name	Reach number	River km
Menemen	12.0	26.5
Manisa	10.0	60.0
Turguthu	5.0	95.0
Salihli	2.0	175.0
Alaşehir	1.0	200.0
Saruhanlı	8.0	15.0
Akhisar	6.0	48.0
Ahmetli	3.0	150.0

**Figure 5.2 The Locations of Domestic Wastewater Discharges.**

Using the above sets of information, the river system can be schematized on the screen as in Figure 5.3.

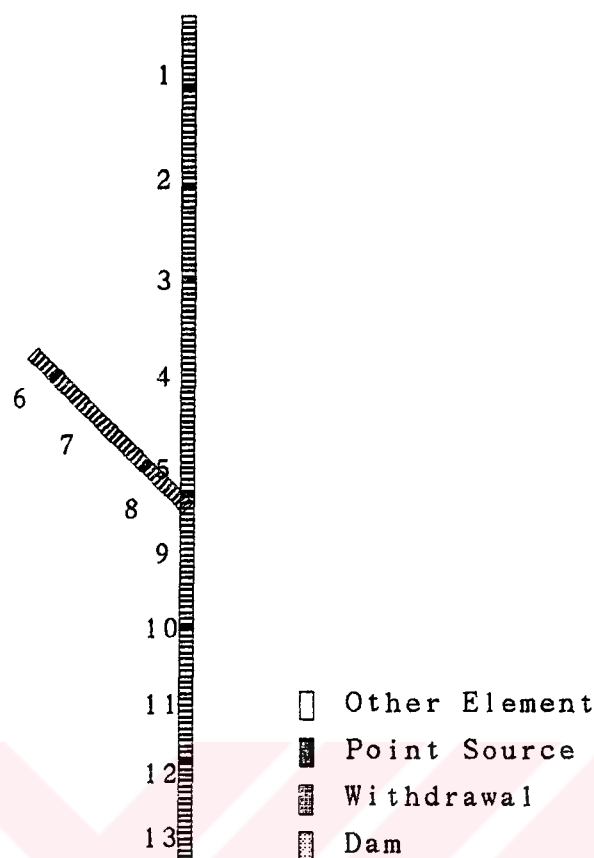


Figure 5.3 Schematized River System.

On “Water quality data” screen, the water quality variables to be simulated are identified. Among the 15 water quality constituents that can be modeled with QUAL2E, 10 of them are selected in the scope of this study. Again on this screen, BOD can be defined as either 5-D BOD or ultimate BOD. Downstream boundary constituent concentrations can be specified if desired. These data are given in Table 5.5.

Table 5.5 “Water Quality Data” Set.

☐ Temperature ☒ BOD ☐ Algae ☒ P cycle ☒ N cycle ☒ DO ☐ Fecal coliform	☒ Conservative constituents Number of constituents 2 Constituent No 1 SS mg/l Constituent No 2 EC $\mu\text{mho/cm}$ Constituent No 3
	☐ Non conservative constituent
	☐ Specified d/s boundary constituent concentration
	☐ BOD5 Coefficient for converting 5-D to ultimate BOD 0.23

On Screen 5, geographical data and climatological data types should be entered. These data are given in Table 5.6. In this data set, the climatological data section should not be entered for dynamic simulation.

Table 5.6 Geographical and Climatological Data Set.

Latitude (deg)	34	AE ((m/h)/(m/bar))	6.2E-06
Longitude (deg)	85	BE ((m/h)/(m/bar))	5.5E-06
Standard meridian (deg)	75	Temperature correction factors	
Basin elevation (m)	304.8	☒ Default	
Dust attenuation coefficient	0.06	☐ User specified	
Climatological data		Output Print	
☒ Reach variable temperature		☒ Summary	
☐ Global values		☐ Climatological data printout	
Climatological file			
☒ DO/BOD plot			
Number of DO/BOD plots		2	Observed DO file

On Screen 6, the reach numbers to be plotted and the number of observed dissolved oxygen stations are entered as given in Table 5.7.

Table 5.7 Reach Numbers for DO/BOD to be Plotted.

Plot No	No. loc.	1	2	3	4	5	6	7	8	9	10	11	12	13
1	4	√	√	√	√	√				√	√	√	√	√
2	1						√	√	√					

On Screen 7, the observed dissolved oxygen data are entered. 4 locations on the main stream and 1 location on the tributary, altogether 5 locations, are selected. Because only a single value of dissolved oxygen is available at a given location, this value is entered in the minimum data position. The data set is given in Table 5.8.

Table 5.8 Observed Dissolved Oxygen Data Set.

Plot	River location (km)	Min DO (mg/l)	Ave DO (mg/l)	Max DO (mg/l)
1	190.0	8.3	0.0	0.0
1	120.0	8.5	0.0	0.0
1	60.0	8.3	0.0	0.0
1	30.0	9.1	0.0	0.0
2	50.0	8.2	0.0	0.0

On Screen 8, global kinetics data are entered. For purposes of the presented study, only *oxygen uptake by ammonia* and *nitrite oxidation* and *nitrification inhibition coefficient* can be entered because of the selected constituents. If algae simulation has been selected, then all the items on this screen could be entered. For these data, the default values are used. The items on Screen 8 are given in Table 5.9.

Table 5.9 Global Kinetics Data Set.

Oxygen uptake by		Light	
Ammonia oxidation	3.43	Light function	
Nitrite oxidation	1.14	Saturation coeff.	0.0298
Algae		Intensity	352.82
Oxygen production by growth	1.6	Light averaging from solar radiation	
Oxygen uptake by respiration	2.0	Light averaging factor	0.923
Nitrogen content	0.085	Number of daylight hours	14
Phosphorus content	0.014	Daily radiation	352.82
Max. specific growth rate	2.5	Light nutrient reactions	
Respiration rate	0.05	Algal preference factor for NH ₃	0.9
N half saturation coefficient	0.2		
P half saturation coefficient	0.04	Solar radiation factor	0.44
Linear coefficient	0.00246	Nitrification inhibition coefficient	10
Nonlinear coefficient	0.0		

On Screen 9, temperature correction factors can be set. Again on this screen, temperature correction factors should be entered according to the selected modeled parameters. If there is no measured value, as in this study, the default values can be used. This screen and the values are given in Table 5.10.

Table 5.10 Temperature Correction Factors.

BOD		Phosphorus	
Decay	1.047	Organic P decay	1.047
Settling	1.024	Organic P settling	1.024
		Dissolved P source	1.047
DO		Algae	
Reaeration	1.024	Growth	1.047
SOD uptake	1.060	Respiration	1.047
		Settling	1.024
Nitrogen		Coliform decay	
Org-N decay	1.047		1.047
Org-N settling	1.024	Nonconservative	
Ammonia decay	1.083	Decay	1.000
Ammonia source	1.074	Settling	1.024
Nitrite decay	1.047	Source	1.000

Because flow augmentation option is not selected, this group of data are not entered for Screen 10.

On Screen 11, hydraulic and climatological data should be entered. Since "Trapezoidal channels" option is not selected, values for the "Discharge coefficients" option are set on this screen. Again "reach variable climatological data" option is not selected so that reach variable climatological data are not entered on this screen.

In this study, with the cross-sectional areas of Baklacı, Urganlı, Medar and Muradiye streams and values of the "Q-h diagrams" measured by EIE, velocity and height values are calculated according to the "Discharge coefficients" technique. In Table 5.11, the cross-sectional area and flow values are given for each reach.

Table 5.11 Cross-sectional Areas and Q-h Values for the Selected Reaches.

Reach Number	Cross-sectional Area	"Q-h diagram" values
1-2	Baklacı stream	Baklacı Station
3-4-5	Urganlı stream	Baklacı Station
6	Medar stream	Medar Station
7-8	Medar stream	Killik Station
9-10-11-12-13	Muradiye stream	Manisa Station

Hydraulic data are set according to discharge coefficients. According to the method, the velocity is calculated to the $V = a Q^b$ equation and height is calculated with $D = c Q^d$ equation. For each reach, the dispersion constant (K), a, b, c and d coefficients and "n" Manning's coefficient are calculated according to the cross-sectional areas of the reaches.

The calculated values are entered as in Tables 5.12, 5.13, 5.14, 5.15, 5.16. In Table 5.17 only the calculated hydraulic values are given.

Table 5.12 The Hydraulic Computations for the Baklacı Streamgaging Station According to the Annual Reports of EIE.

h (m)	ln h	Q (m ³ /s)	ln Q	V (m/s)	ln V
4.8	1.569	0.00	∞	0.000	∞
4.9	1.589	0.08	-2.526	0.044	-3.124
5.0	1.609	0.26	-1.347	0.089	-2.419
5.1	1.629	0.59	-0.528	0.139	-1.973
5.2	1.649	1.20	0.182	0.195	-1.635
5.3	1.668	2.12	0.751	0.242	-1.419
5.4	1.686	3.60	1.281	0.287	-1.248
5.5	1.705	5.65	1.732	0.440	-0.821
5.8	1.758	15.00	2.708	0.808	-0.213
6.0	1.792	25.00	3.219	2.074	0.729

$$V = 0.180 Q^{0.604}, a = 0.180, b = 0.604$$

$$h = 5.232 Q^{0.035}, c = 5.232, d = 0.035$$

Table 5.13 The Hydraulic Computations for the Urganlı Streamgaging Station According to the Annual Reports of EIE.

h (m)	ln h	Q (m ³ /s)	ln Q	V (m/s)	ln V
4.8	1.569	0.00	∞	0.000	∞
4.9	1.589	0.08	-2.526	0.010	-4.605
5.0	1.609	0.26	-1.347	0.020	-3.912
5.1	1.629	0.59	-0.528	0.034	-3.381
5.2	1.649	1.20	0.182	0.049	-3.016
5.3	1.668	2.12	0.751	0.066	-2.718
5.4	1.686	3.60	1.281	0.086	-2.453
5.5	1.705	5.65	1.732	0.143	-1.945
5.8	1.758	15.00	2.708	0.235	-1.448
6.0	1.792	25.00	3.219	0.637	-0.451

$$V = 0.047 Q^{0.668}, a = 0.047, b = 0.668$$

$$h = 5.232 Q^{0.035}, c = 5.232, d = 0.035$$

Table 5.14 The Hydraulic Computations for the Medar Streamgaging Station According to the Annual Reports of EIE.

h (m)	ln h	Q (m ³ /s)	ln Q	V (m/s)	ln V
0.35	-1.050	0.150	-1.897	0.012	-4.423
0.40	-0.916	0.290	-1.238	0.028	-3.576
0.50	-0.693	0.770	-0.261	0.069	-2.674
0.60	-0.511	1.650	0.501	0.128	-2.056
0.70	-0.357	2.950	1.082	0.196	-1.630
0.80	-0.223	4.800	1.569	0.272	-1.302
0.90	-0.105	6.900	1.932	0.346	-1.061
1.00	0.000	9.700	2.272	0.429	-0.846
1.50	0.405	29.00	3.367	0.871	-0.138
2.00	0.693	56.50	4.034	1.128	0.120

$$V = 0.073 Q^{0.756}, a = 0.073, b = 0.756$$

$$h = 0.547 Q^{0.288}, c = 0.547, d = 0.288$$

Table 5.15 The Hydraulic Computations for the Killik Streamgaging Station According to the Annual Reports of EIE.

h (m)	ln h	Q (m ³ /s)	ln Q	V (m/s)	ln V
0.55	-0.598	0.100	-2.303	0.021	-3.863
0.60	-0.511	0.520	-0.654	0.056	-2.882
0.70	-0.357	1.450	0.372	0.089	-2.419
0.80	-0.223	2.300	0.833	0.119	-2.129
0.90	-0.105	3.260	1.182	0.148	-1.911
1.00	0.000	4.400	1.482	0.180	-1.715
1.50	0.405	13.90	2.632		
2.00	0.693	30.00	3.401	0.574	-0.555
2.50	0.916	54.00	3.989	0.829	-0.188
3.50	1.253	131.0	4.875		

$$V = 0.077 Q^{0.580}, a = 0.077, b = 0.580$$

$$h = 0.745 Q^{0.280}, c = 0.745, d = 0.280$$

Table 5.16 The Hydraulic Computations for the Menemen Streamgaging Station According to the Annual Reports of EIE.

h (m)	ln h	Q (m ³ /s)	ln Q	V (m/s)	ln V
0.70	-0.357	7.00	1.946	0.394	-0.931
0.80	-0.223	11.20	2.416	0.429	-0.846
0.90	-0.105	15.60	2.747	0.469	-0.757
1.00	0.000	20.20	3.006	0.516	-0.662
1.50	0.405	43.80	3.780	0.687	-0.375
2.00	0.693	74.00	4.304	0.918	-0.086
2.50	0.916	109.0	4.691	1.029	0.029
3.00	1.099	146.0	4.984	1.167	0.154
4.00	1.386	247.0	5.509	1.341	0.293
5.00	1.609	400.0	5.991	1.454	0.374

$$V = 0.185 Q^{0.357}, a = 0.185, b = 0.357$$

$$h = 0.232 Q^{0.509}, c = 0.232, d = 0.509$$

Table 5.17 Hydraulic and Climatological Data Set.

Reach No	Disp. Cons.	Q Coeff. Velocity	Q Expo. Velocity	Q Coeff. depth	Q Expo. depth	Manning n
1	200	0.180	0.604	5.232	0.035	0.05
2	200	0.180	0.604	5.232	0.035	0.05
3	6000	0.047	0.668	5.232	0.035	0.05
4	6000	0.047	0.668	5.232	0.035	0.05
5	6000	0.047	0.668	5.232	0.035	0.05
6	146	0.073	0.756	0.547	0.288	0.05
7	146	0.077	0.580	0.745	0.280	0.05
8	146	0.077	0.580	0.745	0.280	0.05
9	436	0.185	0.357	0.232	0.509	0.05
10	436	0.185	0.357	0.232	0.509	0.05
11	436	0.185	0.357	0.232	0.509	0.05
12	436	0.185	0.357	0.232	0.509	0.05
13	436	0.185	0.357	0.232	0.509	0.05

On Screen 12, BOD/DO reaction rate constants should be set. These values are determined according to literature values and are given in Table 5.18.

Table 5.18 BOD/DO Reaction Rate Constants Data Set.

Reach No	BOD Decay(1/d)	BOD Sett.(1/d)	SOD rate	Type reaeration	Reaction Coeff.	Coeff. (1/d)	Expo.
1	1.5	1		Churchill	5.03	1	1.67
2	1.5	1		Churchill	5.03	1	1.67
3	1.5	1		Churchill	5.03	1	1.67
4	1.5	1		Churchill	5.03	1	1.67
5	1.5	1		Churchill	5.03	1	1.67
6	1.5	1		Churchill	5.03	1	1.67
7	1.5	1		Churchill	5.03	1	1.67
8	1.5	1		Churchill	5.03	1	1.67
9	1.5	1		Churchill	5.03	1	1.67
10	1.5	1		Churchill	5.03	1	1.67
11	1.5	1		Churchill	5.03	1	1.67
12	1.5	1		Churchill	5.03	1	1.67
13	1.5	1		Churchill	5.03	1	1.67

On Screen 13, nitrogen, phosphorus, algae and other coefficients are set. All these data are taken from literature values and presented in Table 5.19.

Table 5.19 N, P, Algae and Other Coefficients Data Set.

No	O-N Hyd.	O-N Sett.	NH3 Oxi.	NH3 Bent.	NO2 Oxi.	O-P Dec.	O-P Sett.	Dis P Bent.	Chl-a Alg.	Alg. Sett.	Lig. ext.
1	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
2	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
3	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
4	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
5	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
6	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
7	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
8	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
9	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
10	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
11	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
12	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	
13	0.5	0.05	0.5	0	2	0.3	0.06	0	10	0.305	

On Screen 14, initial conditions data can be entered. Since these data are required for dynamic simulation, they are not filled in for the steady-state simulation.

On Screen 15, incremental inflow/outflow values can be set if incremental flow is used in the simulation. Incremental flow values are entered for each reach to represent the contribution of runoff from the drainage areas surrounding the reach. These values are determined by using the average flow rates of existing streamgaging stations. This group of data includes the flow and quality characteristics of the modeled variables. The annual incremental flow data set is given in Table 5.20. Incremental data are given in m^3/sec for flow and mg/lt for quality data with EC expressed in $\mu\text{mhos}/\text{cm}$.

Table 5.20 The Incremental Flow Data Set (IF: Incremental Flow Number).

IF	Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃ -N	NO ₂ -N	NO ₃ -N	O-P	Dis P
1	0.0	21.1										
2	4.0	21.1	8.5	1.8	505	750		0.0	0.5	2.1		0.1
3	20.0	21.1	8.6	2.0	150	510		0.0	0.03	0.95		0.25
4	5.0	21.1	8.7	2.1	185	600			0.04	1.1		0.3
5	5.0	21.1	8.8	2.3	203	820			0.05	1.5		0.2
6	0.0	21.1										
7	5.0	21.1										
8	3.0	21.1										
9	5.0	21.1	7.5	2.2	130	530		0.06	0.18	1.78		0.61
10	2.0	21.1	7.0	2.4	200	570		0.0	0.20	1.8		0.5
11	3.0	21.1	8.9	2.3	160	650		0.0	0.15	1.5		0.55
12	2.0	21.1	9.1	2.0	233	566			0.036	1.2		0.35
13	3.0	21.1	9.0	1.9	211	630			0.020	0.95		0.40

On Screen 16, headwater data can be entered. This group of data is necessary to simulate the river system. The entered data set is given in Table 5.21 with the same units used as in Table 5.20.

Table 5.21 Headwater Data Set (HW: Headwater number).

HW	Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃ -N	NO ₂ -N	NO ₃ -N	O-P	DisP
1	1.029	16.4	8.3	1.5	469	696		0.0	0.418	1.92		0.08
2	1.46	14.0	9.8		134	873		0.0	0.016	1.2		0.27

On Screen 17, point load and withdrawal values are required. In this study, domestic wastewaters are taken into consideration. Domestic wastewater sources are the villages located in the basin. They are: Menemen, Manisa, Turgutlu, Salihli, Alaşehir, Saruhanlı, Akhisar, and Ahmetli. The amount of wastewater per capita per day is taken as $0.2 \text{ m}^3/\text{ca.d.}$ According to the 1990 population of the residential areas given in Table 4.1, the domestic wastewater discharges are calculated as in Table 5.22.

Table 5.22 Domestic Wastewater Discharges in the Basin.

Name	Population (ca)	Q (m ³ /d)	Q (m ³ /s)
Menemen	29 429	5886	0.068
Manisa	2 200 000	440 000	5.093
Turgutlu	68 173	13 635	0.158
Salihli	71 418	14 284	0.165
Alaşehir	32 302	6 460	0.075
Saruhanlı	12 776	2 555	0.030
Akhisar	75 711	15 142	0.175
Ahmetli	8 875	1 775	0.021

The quality values of the modeled variables relevant to domestic wastewater are used as the literature values as given in Table 5.23. Treatment fraction (TF) of each domestic wastewater discharge is assumed as zero - "0".

Table 5.23 Quality Values of the Modeled Variables.

Parameter	Value	Parameter	Value
Temperature(°C)	20	NO ₂ -N (mg/l)	0
BOD (mg/l)	220 (110-440)	NO ₃ -N (mg/l)	0
TDS (mg/l)	500 (250-850)	Org-P (mg/l)	3 (1-5)
Org-N (mg/l)	15 (8-35)	Dis-P (mg/l)	5 (3-10)
NH ₃ -N (mg/l)	25 (12-50)		

The replacement of point loads in the river system - the number of reach and the river kilometers - are given in Table 5.4.

After all the above computations on Screen 17, the data given in Table 5.24 are obtained. The table expressed flow in m³/sec, temperature in °C, and quality variables in mg/l.

Table 5.24 Point Load Data Set.

Name	TF (%)	Flow	Temp	DO	BOD	SS
Alaşehir	0	0.042	20	0	200	500
Salihli	0	0.061	20	0	250	600
Turgutlu	0	0.047	20	0	300	600
Ahmetli	0	0.009	20	0	200	520
Akhisar	0	0.071	20	0	250	450
Saruhanlı	0	0.034	20	0	200	500
Manisa	0	0.103	20	0	400	550
Menemen	0	0.035	20	0	250	600

Table 5.24 (continued).

Name	Org N	NH3-N	NO2-N	NO3-N	Org-P	Dis-P
Alaşehir	20	20	0	0	5	5
Salihli	20	30	0	0	5	5
Turgutlu	20	25	0	0	5	5
Ahmetli	20	25	0	0	5	5
Akhisar	15	25	0	0	3	5
Saruhanlı	15	25	0	0	3	5
Manisa	15	25	0	0	3	5
Menemen	15	25	0	0	3	5

Because there is no dam reaeration and downstream boundary conditions, this group of data are not entered.

Since steady-state simulation is used in the study, climatological data should be set as global values. Global climatological data are entered on Screen 20 and presented in Table 5.25. These data are obtained from DMI (State Meteorological Works). The data obtained from DMI are given in Appendix F. Since the climatological data are reach variable, for reaches 1 to 5, Alaşehir village data; for reach 6, Akhisar village data; for reaches 7 and 8, Salihli village data and for reaches through 9 to 13, Manisa village data are used. Global values are also determined from these data set.

Table 5.25 Global Climatological Data Set.

Month	Day	Year	Hour	Solar Rad.	Cloud cover	Dry Temp.	Wet Temp.	Baro. Press.	Wind speed
6	15	1983	12			15.6	42.5	1017.0	1.7

In order to determine the seasonal variations of the simulated variables, the model is run for 4 seasons in a steady-state simulation mode. In these seasonal simulations, all the input data except headwater, global climatological and incremental flow data are the same as the annual values. The values of headwater and global climatological data of each season are given in Tables 5.26, 5.27, 5.28, 5.29, and similarly, the values of incremental flow data are given in Table 5.30, 5.31, 5.32 and 5.33 respectively for winter, spring, summer and autumn. In all these tables, flow is expressed in (m^3/sec) and quality variables in (mg/l) (EC in $\mu\text{mho}/\text{cm}$).

Table 5.26 Input Data for Winter.

Headwater data											
Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃	NO ₂	NO ₃	O-P	σP
1.06	11.5	10.4		2029	900		0.0		0.50		
3.80	8.0	13.0		42.0	295		0.0		1.25		
Global climatological data											
Month	Day	Year	Hour								
2	15	1983	12								

Table 5.27 Input Data for Spring.

Headwater data											
Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃	NO ₂	NO ₃	O-P	σP
2.12	11.5	10.6		309	320		0.0	0.026	1.60		
2.35	16.0	10.2		374	400		0.0	0.023	0.56		
Global climatological data											
Month	Day	Year	Hour								
4	15	1983	12								

Table 5.28 Input Data for Summer.

Headwater data											
Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃	NO ₂	NO ₃	O-P	σP
0.90	30.0	6.50		213	790		0.0	0.030	0.95		0.05
0.65	24.0			287	485		0.0	0.007	1.20		0.10
Global climatological data											
Month	Day	Year	Hour								
6	15	1983	12								

Table 5.29 Input Data for Autumn.

Headwater data											
Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃	NO ₂	NO ₃	O-P	σP
0.76	18.0	8.20		823	990		0.0	0.250	0.70		0.12
0.65											
Global climatological data											
Month	Day	Year	Hour								
10	15	1983	12								

Table 5.30 Input Incremental Flow Data for Winter (IF: Incremental Flow Number).

IF	Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃ -N	NO ₂ -N	NO ₃ -N	O-P	Dis P
1		21.1										
2	1.3	21.1	9.5	2.0	2030	850				0.82		0.05
3	18.5	21.1	11.9	1.3	50	415				1.3		
4	19.0	21.1	11.0	1.5	85	500				1.5		
5	21.0	21.1	12.0	1.8	110	480				1.2		
6		21.1										
7		21.1										
8		21.1										
9	55.0	21.1	8.0	3.2	27	390				1.25		
10	50.0	21.1	7.8	2.0	30	400				1.3		
11	60.0	21.1	9.5	4.0	40	410				1.35		
12	65.0	21.1	8.4		407	330				1.35		
13	72.0	21.1	8.5		420	325				1.4		

Table 5.31 Input Incremental Flow Data for Spring (IF: Incremental Flow Number).

IF	Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃ -N	NO ₂ -N	NO ₃ -N	O-P	Dis P
1		21.1										
2	2.0	21.1	11.0	1.2	309	320			0.026	1.6		
3	32.0	21.1	10.4	1.5	253	290			0.02	0.4		
4	35.0	21.1	10.6	1.8	200	300			0.15	0.35		
5	37.0	21.1	11.0	1.6	260	295			0.22	0.3		
6		21.1										
7		21.1										
8		21.1										
9	36.7	21.1	8.3	2.0	319	350			0.028	1.1		
10	37.0	21.1	8.0	1.8	310	345			0.03	1.0		
11	38.0	21.1	7.9	1.5	300	355			0.032	1.15		
12	85.0	21.1	8.2		320	440			0.036	1.4		
13	87.0	21.1	8.1		315	400			0.03	1.2		

Table 5.32 Input Incremental Flow Data for Summer (IF: Incremental Flow Number).

IF	Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃ -N	NO ₂ -N	NO ₃ -N	O-P	Dis P
1		21.1										
2	0.9	21.1	6.5		213	790		0.0	0.03	0.95		0.05
3	5.2	21.1	8.0		167	900		0.0	0.05	0.95		0.2
4	5.0	21.1	8.2		170	920		0.0	0.06	1.0		0.22
5	5.6	21.1	8.1		175	930		0.0	0.055	1.1		0.25
6		21.1										
7		21.1										
8		21.1										
9	13.2	21.1	7.7		291	675		0.0	0.025	2.05		0.36
10	13.0	21.1	7.8		290	680		0.0	0.03	2.1		0.4
11	15.0	21.1	8.0		310	700		0.0	0.035	2.3		0.45
12	17.1	21.1	8.0		309	650		0.0	0.01	0.1		0.1
13	18.0	21.1	8.2		310	680		0.0	0.12	0.12		0.1

Table 5.33 Input Incremental Flow Data for Autumn (IF: Incremental Flow Number).

IF	Flow	Tem	DO	BOD	SS	EC	O-N	NH ₃ -N	NO ₂ -N	NO ₃ -N	O-P	Dis P
1		21.1										
2	0.7	21.1			823	990			0.025	0.7		0.12
3	5.6	21.1	9.6		561	620		0.0	0.04	1.0		
4	5.8	21.1	9.8		570	630		0.0	0.06	1.1		
5	6.0	21.1	11.0		580	650		0.0	0.055	1.2		
6		21.1										
7		21.1										
8		21.1										
9	44.8	21.1	9.4		406	735		0.0	0.034	1.92		0.42
10	45.0	21.1	9.6		420	750		0.0	0.036	2.0		0.45
11	48.0	21.1	10.0		450	800		0.0	0.04	2.1		0.5
12	54.0	21.1	9.6		604	730		0.0	0.017	0.95		0.45
13	55.0	21.1	10.0		620	750		0.0	0.02	1.0		0.5

5.3 Application of the Model

5.3.1 General

As stated in the previous section, the model is run for the water quality variables; DO, BOD, N cycle (organic, ammonia, nitrite and nitrate nitrogen), P cycle (organic and dissolved phosphorus), suspended solids and electrical conductivity. In the first step, the model is run with the annual values of runoff and water quality. Since the most complete set of water quality observations in the Gediz basin are available for 1983, the data of this year are used to represent the annual values. Using these values, the results are obtained in the form of graphs and tables for each modeled variable along the main stream and the tributary.

In the second step, the model is prepared according to the seasonal values of water quality variables. The model is run for each season again using 1983 values for each season. The graphical results for each modeled variable are obtained for the main stream and the tributary. The resulting tables are developed by the model as a separate file in the program.

5.3.2 Model Run with Annual Values

First, flow versus distance graphs are obtained to see the variation of streamflow along the river. The resulting graphs are shown in Fig. 5.4 for the annual values. On the main stream, the quantity of water increases with contribution of the tributary on 91st kilometer. There are increases on the main stream and the tributary contributed by incremental flows and point loads in the form of domestic discharges. On 200., 175., 150., 90., 60. and 20. kilometers point loads are contributed to the stream, and also on 91st kilometer of the main stream, the tributary contributes.

For the annual values of Biochemical Oxygen Demand (BOD) - the indicator of pollution - the variation of water quality can be observed in Fig. 5.5 along the main stream and the tributary. All the peak points on the graph correspond to the point load contributions which increase the value of BOD on the main stream. The BOD concentrations are dampened at the downstream regions of the river as the river runoff rate increases.

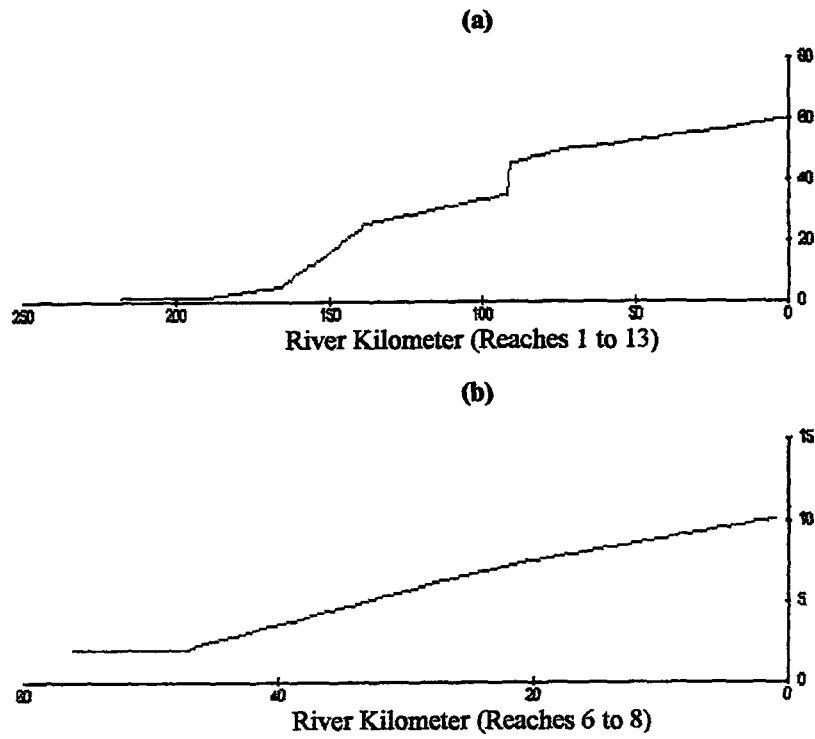


Figure 5.4 Flow vs. distance graphs; (a) on the Main Stream, (b) on the Tributary.

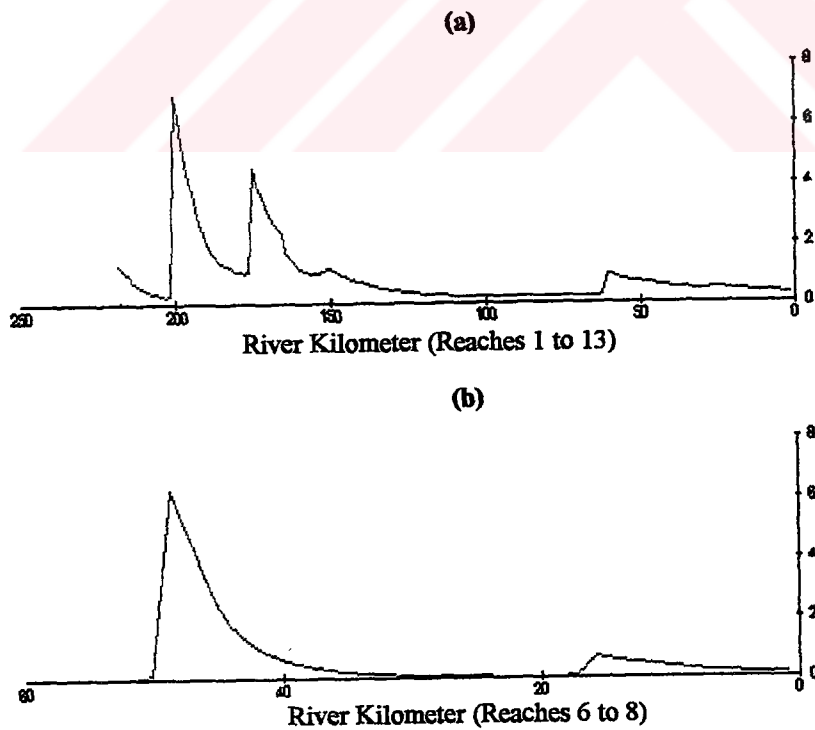


Figure 5.5 BOD (mg/l) (a) on the Main Stream, (b) on the Tributary.

Along the mainstream, DO generally fluctuates around 8 mg/l. It falls below 8 mg/l at the intersection of the tributary. The DO variations along the tributary show a continuous decrease from 10 mg/l to below 2 mg/l at the downstream end. These changes are shown in Fig. 5.6.

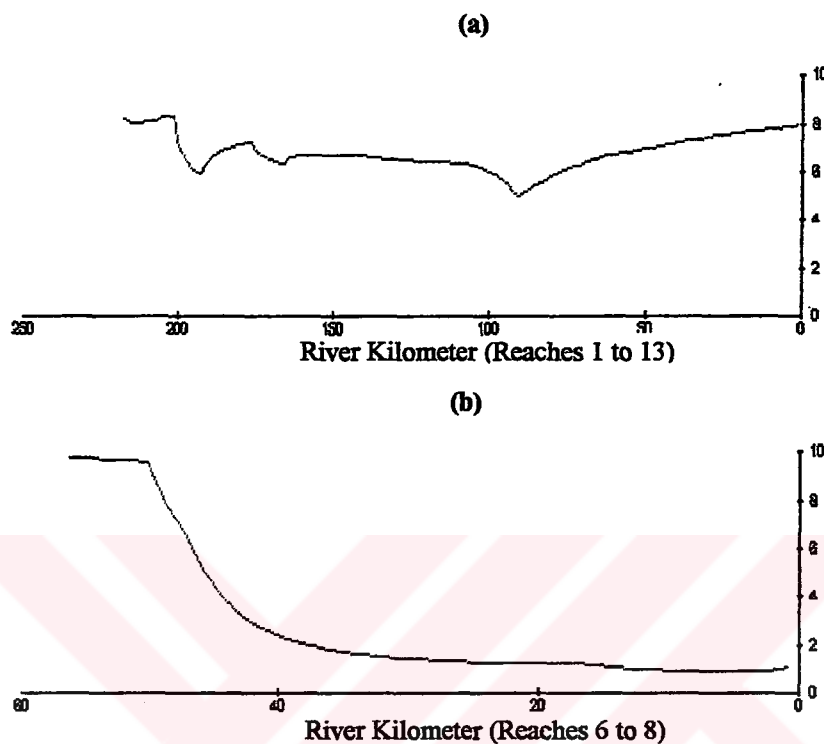


Figure 5.6 DO (mg/l) (a) on the Main Stream, (b) on the Tributary.

Suspended solids (SS), in Fig. 5.7, show a decrease downstream both along the main stream and the tributary as the river flowrates increase. These variations do not show the contributions of irrigation return flows since the latter are not included as inputs to the system. EC essentially follows the same pattern as SS as shown in Fig. 5.8.

Figure 5.9 through 5.12 show that concentrations of organic nitrogen, ammonia nitrogen, nitrite and nitrate are high at points of domestic discharges but they gradually decrease at downstream ends of the main stream and the tributary. Since industrial discharges and irrigation return flows are not considered as inputs, the decreases in these concentrations are essentially expected. These variations are similar to those of BOD of Fig. 5.5.

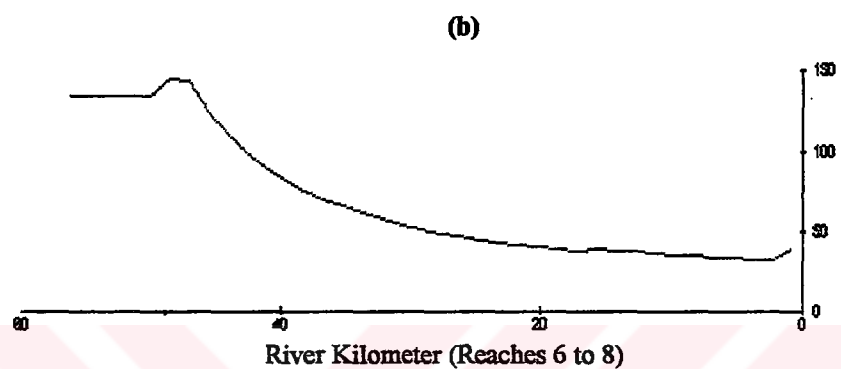
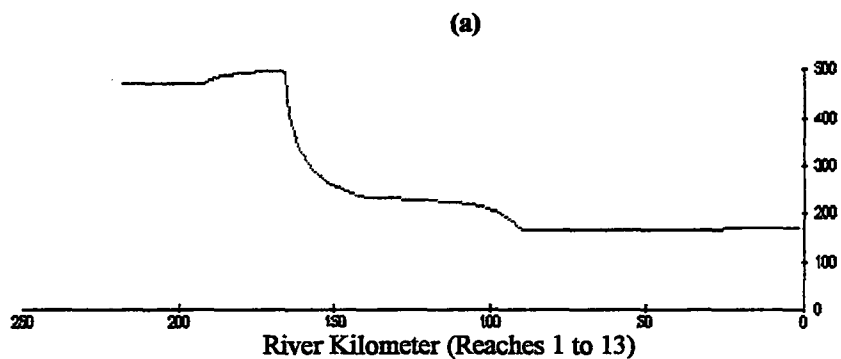


Figure 5.7 SS (mg/l) (a) on the Main Stream, (b) on the Tributary.

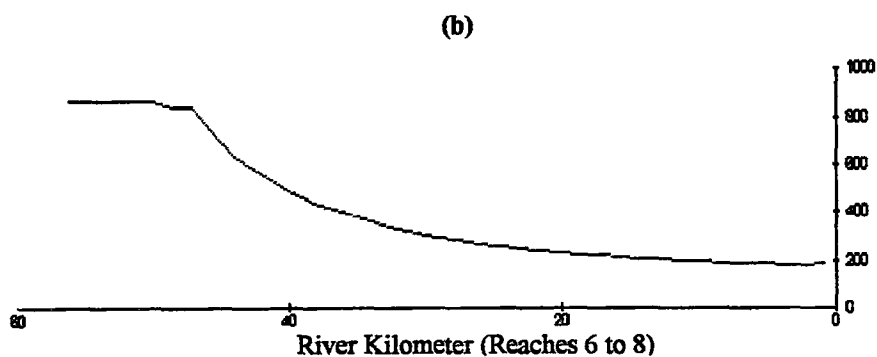
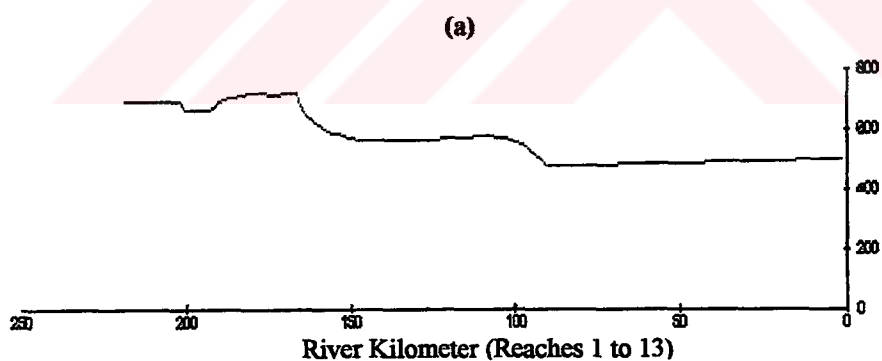


Figure 5.8 EC (μmho/cm) (a) on the Main Stream, (b) on the Tributary.

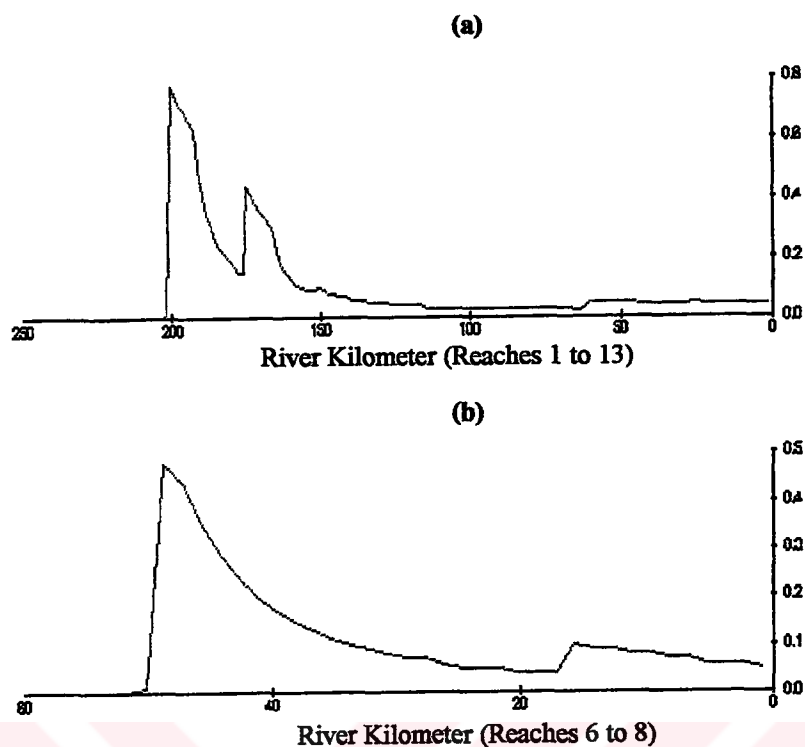


Figure 5.9 Organic Nitrogen (mg/l) (a) on the Main Stream, (b) on the Tributary.

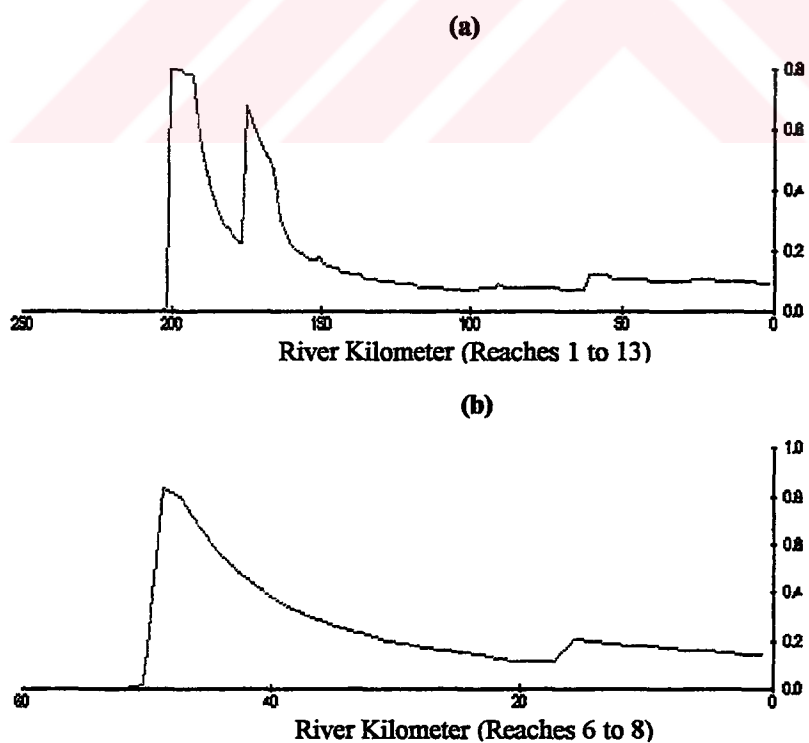


Figure 5.10 Ammonia Nitrogen (mg/l) (a) on the Main Stream, (b) on the Tributary.

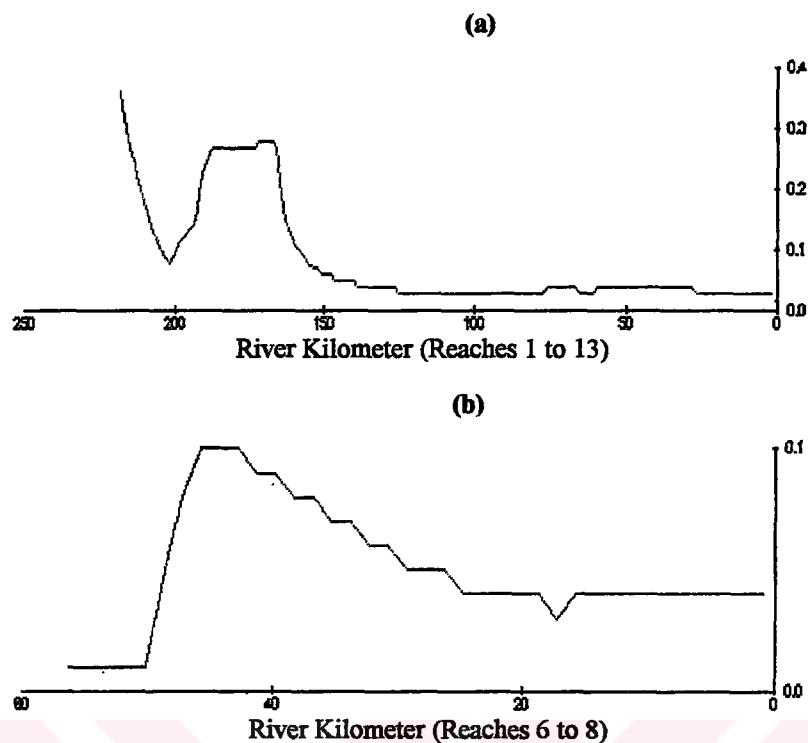


Figure 5.11 Nitrite Nitrogen (mg/l) (a) on the Main Stream, (b) on the Tributary.

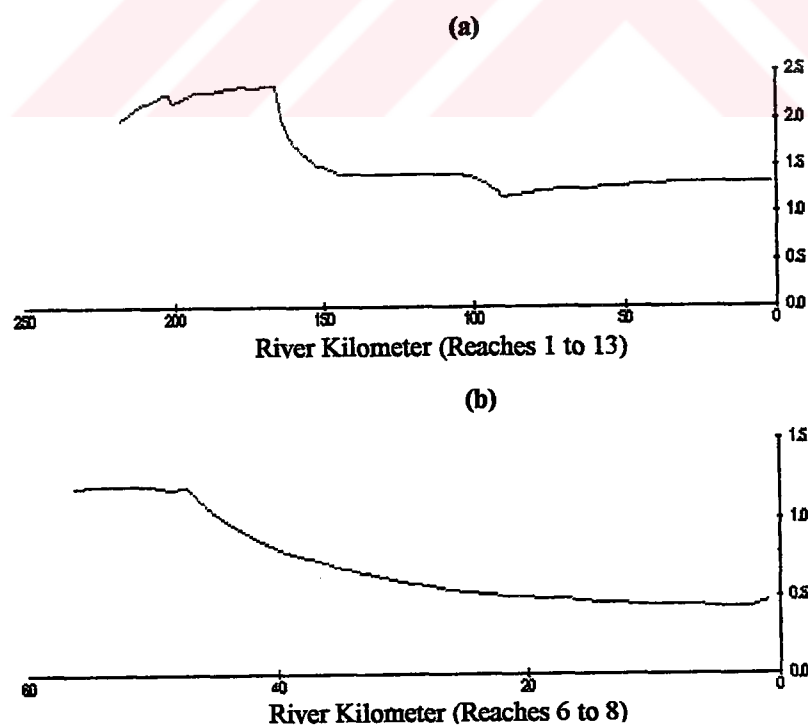


Figure 5.12 Nitrate Nitrogen (mg/l) (a) on the Main Stream, (b) on the Tributary.

The concentrations of organic phosphorus decrease with every point load as shown in Fig. 5.13. After the tributary joins, the concentration is lower than that before the contribution. These variations follow the same pattern of the N-cycle variables.

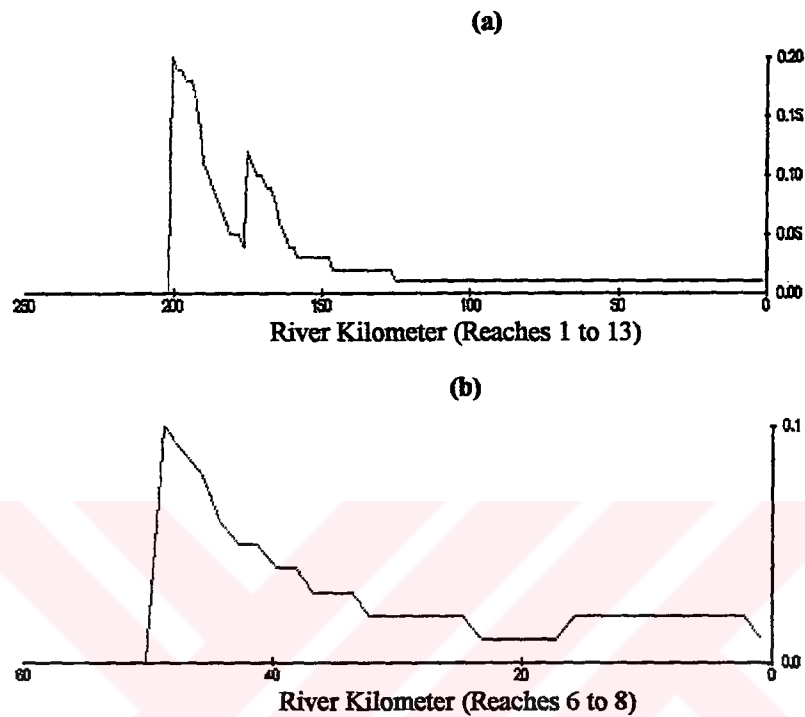


Figure 5.13 Organic Phosphorus (mg/l) (a) on the Main Stream, (b) on the Tributary.

Similarly, dissolved phosphorus concentrations are affected by point loads. Throughout the river, dissolved phosphorus concentration increases along the main stream since observed phosphorus concentrations are entered at a number of points till the downstream end of the river. With the tributary contribution, these increases are slowed down as shown in Fig. 5.14; however, the same pattern is observed after the tributary.

Total phosphorus and nitrogen concentrations are given in Fig. 5.15 and 5.16 respectively. In Sum-P concentrations, there are increases at every point load contribution and they follow the same pattern as dissolved phosphorus concentrations. With the tributary contribution, the rate of increase becomes lower. On the tributary, the only change is due to the point loads. The same situation is valid for Sum-N concentrations.

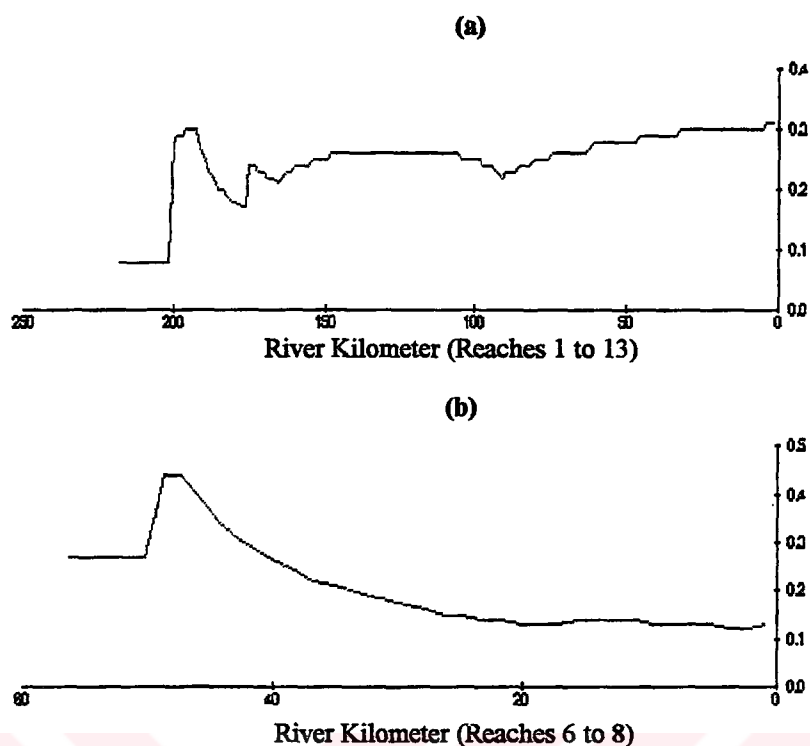


Figure 5.14 Dissolved Phosphorus (mg/l) (a) on the Main Stream, (b) on the Tributary.

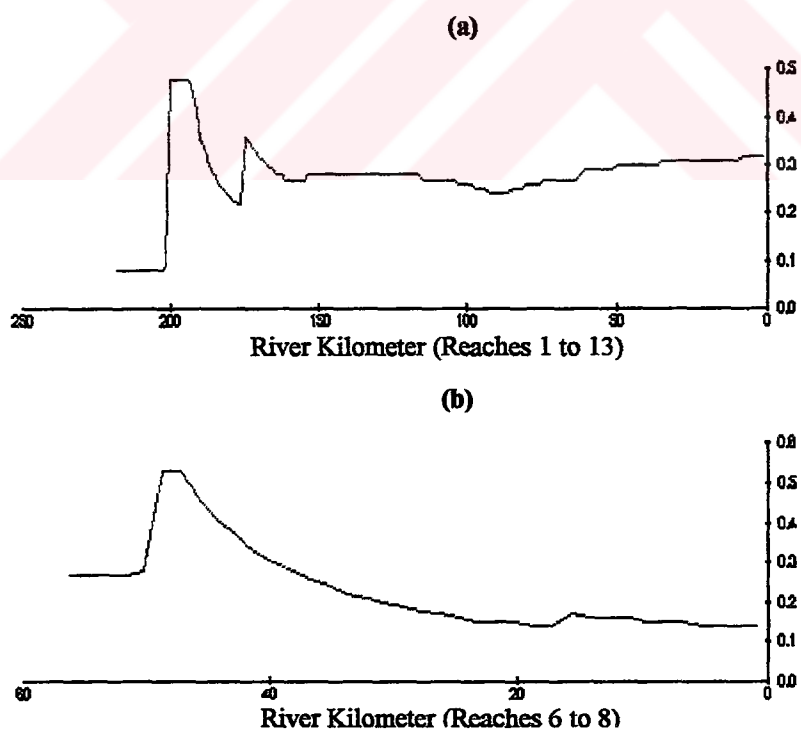


Figure 5.15 Total Phosphorus (Sum-P) (mg/l) (a) on the Main Stream, (b) on the Tributary.

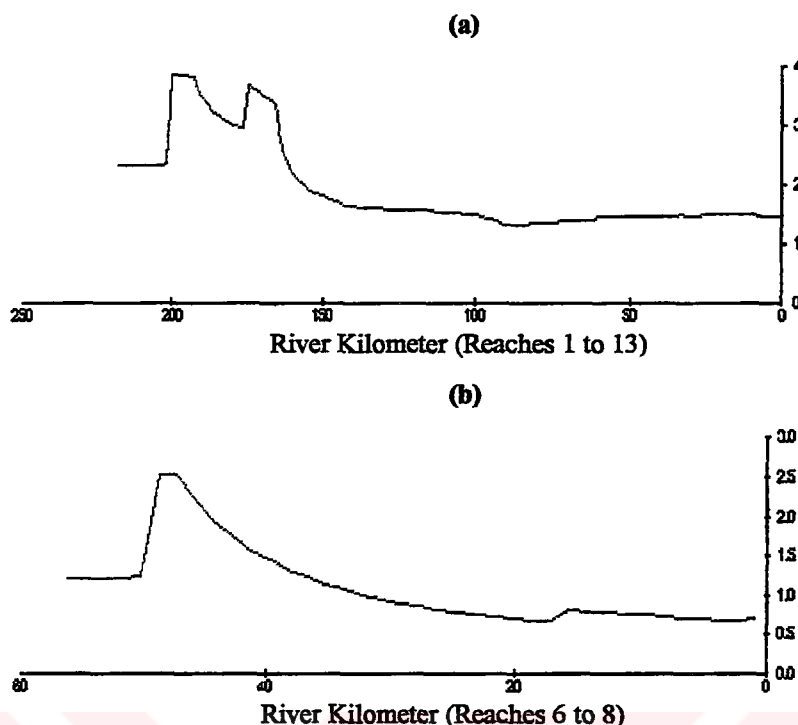


Figure 5.16 Total Nitrogen (Sum-N) (mg/l) (a) on the Main Stream, (b) on the Tributary.

5.3.3 Model Run with Seasonal Values of Water Quality Variables

In the second part of the application, the model is run with values of the quality variables observed in different seasons of 1983.

The variations of BOD show similar trends in all seasons on both the main stream and the tributary. However, the levels of BOD change from a high of 6-8 mg/l in the winter/spring season to 10-15 mg/l in the summer/fall period due to the decreases in river flow rates in the latter season. As shown in Fig. 5.17, wastewater discharges lead to the major variations in BOD so that the river can be rated as belonging to the 2nd quality class.

As shown in Fig. 5.18, DO reflects different variations in the winter/spring and summer/fall seasons. The average value is approximately 8 mg/l in each season; however it falls below this average on the tributary. The addition of point loads leads to distinct decreases in DO concentrations as observed in Fig. 5.18 for the main stream. In all seasons, both the main stream and the tributary show characteristics of the 2nd or the 3rd quality classification.

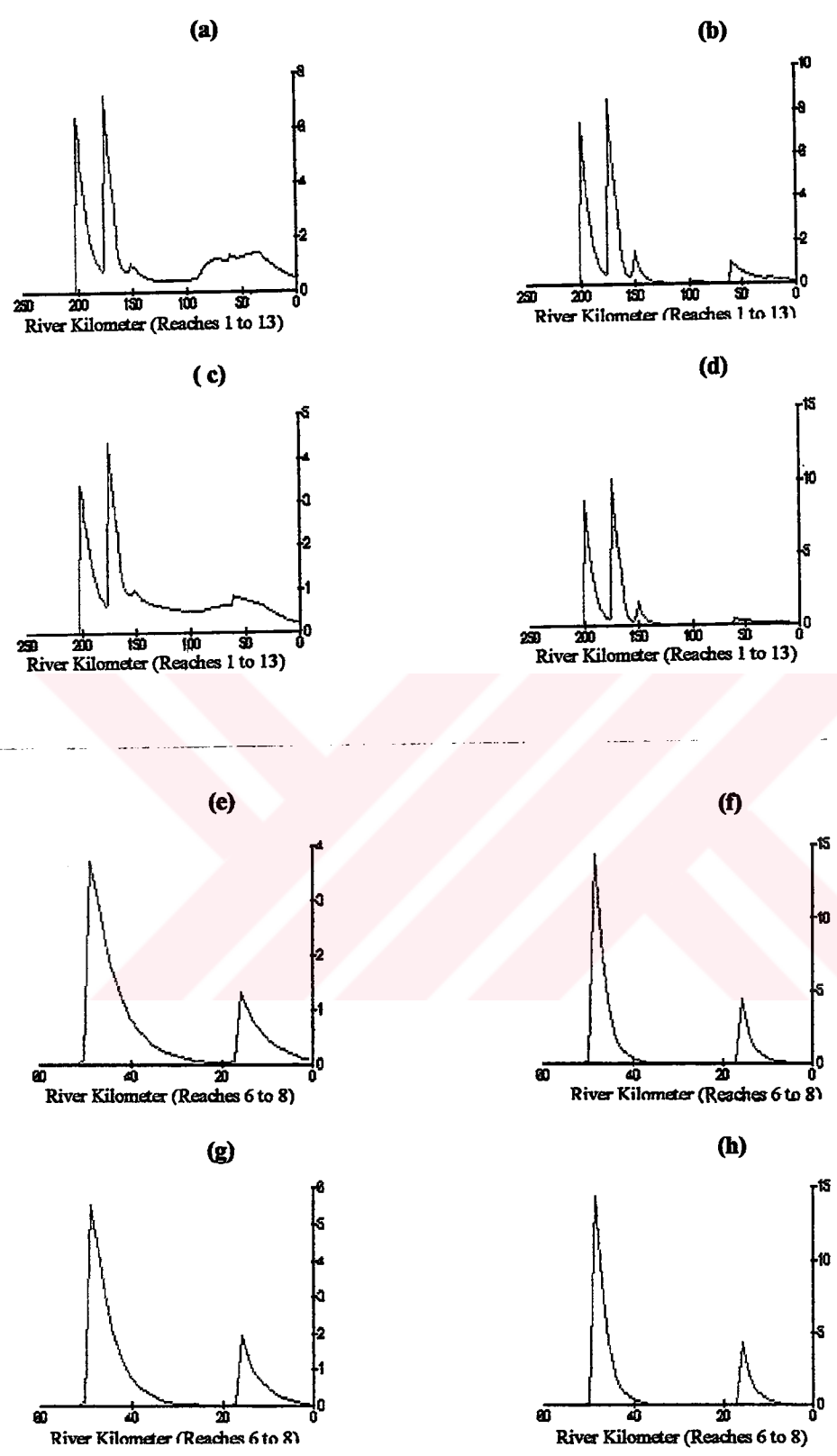


Figure 5.17 BOD (mg/l) on the Main Stream; (a)Winter,(b) Summer, (c)Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

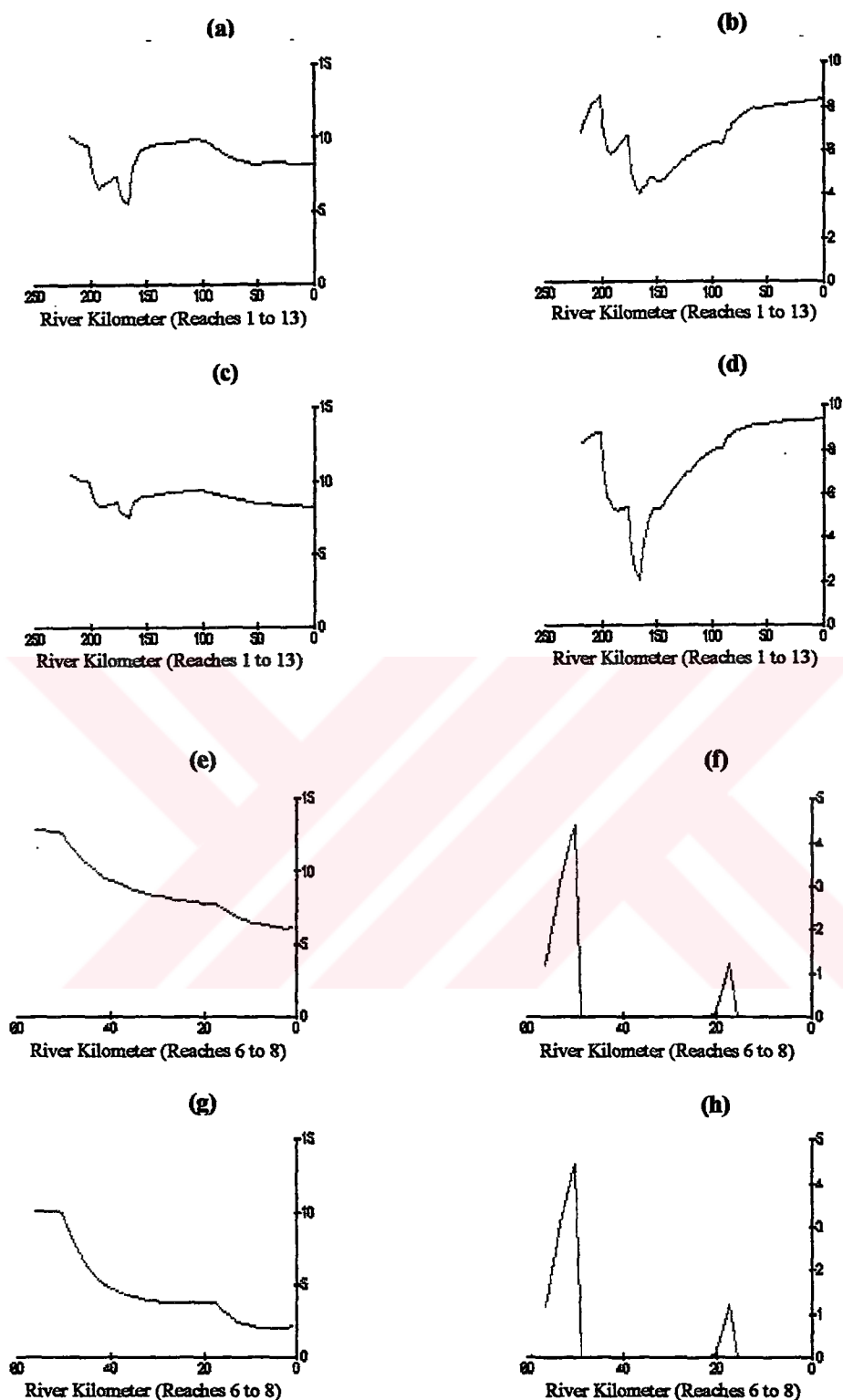


Figure 5.18 Dissolved Oxygen (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

Figure 5.19 indicates seasonal variations in SS concentrations. On the main stream, the concentrations are as high as 600 mg/l in winter/fall and 200-300 mg/l in the spring/summer periods. The effects of point loads do not appear as distinct changes. The basic reason for seasonal variations is the presence of incremental flows. The winter/fall season is the rainy period when the river carries increased levels of sediment; whereas in the spring/summer season, the opposite occurs. On the tributary, SS levels are much lower than those in the main stream. Here, the variations in SS concentrations seem to be affected by point load contributions rather than increased flow rates of the rainy seasons. Thus, the effects of point loads are dampened in the rainy season so that lower levels of SS are observed in the winter/fall period, which is contrary to what happens on the main stream.

EC also reflects seasonal variations as shown in Fig. 5.20. On the main stream, it reaches a level of 600-700 $\mu\text{mho/cm}$ in the winter, fall and summer seasons and decreases to 350 $\mu\text{mho/cm}$ in the spring. The levels decrease downstream in the former seasons but increase in the spring season. On the tributary, similar variations are observed in the summer and the spring with average levels of 420 $\mu\text{mho/cm}$ and 380 $\mu\text{mho/cm}$, respectively. A similar pattern occurs in the winter although the average level decreases to 280 $\mu\text{mho/cm}$. In fall, EC concentrations are observed only at the downstream end of the tributary. In simulation of EC, point loads could not be entered to the model so that the figures shows the variation of the headwater EC concentration along the river. Thus, this variation is affected not by point loads but by incremental river flows.

The variation of Org-N on the main stream does not show differences between the seasons as indicated in Fig. 5.21. However, the levels of Org-N concentrations change from a maximum of 1-2 mg/l in autumn to 0.5 mg/l in the spring, with high values of 0.8 mg/l in the winter and 1.0 mg/l in the summer. On the tributary, summer and fall variations show the same trends at the same levels. Fluctuations in the winter and the spring are also parallel although there are slight variations in the levels. These variations distinctly show the contributions of point domestic discharges. Since, these are the only discharges that could be entered to the model. Essentially, Org-N variations are similar to those of BOD.

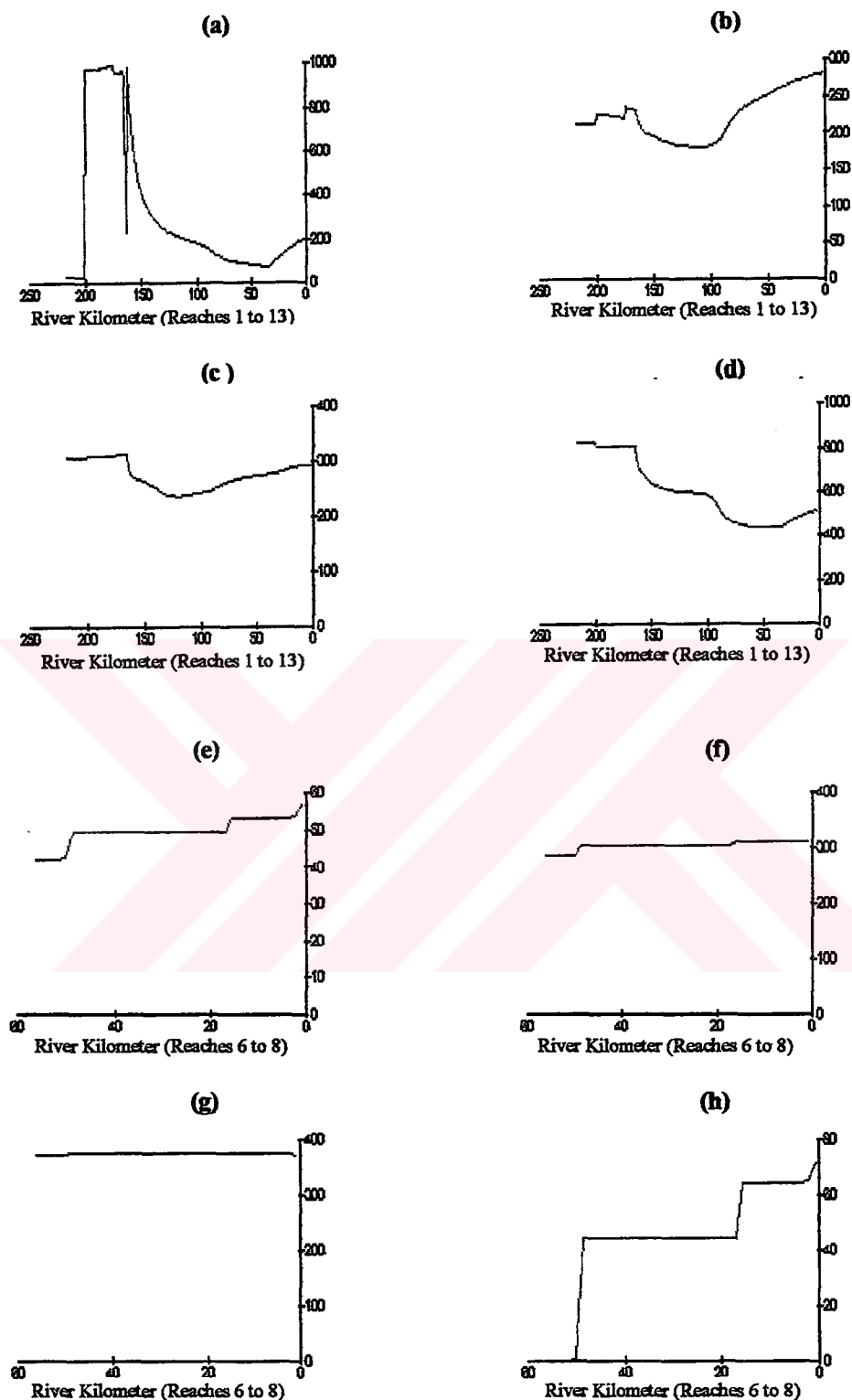


Figure 5.19 Suspended Solids (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

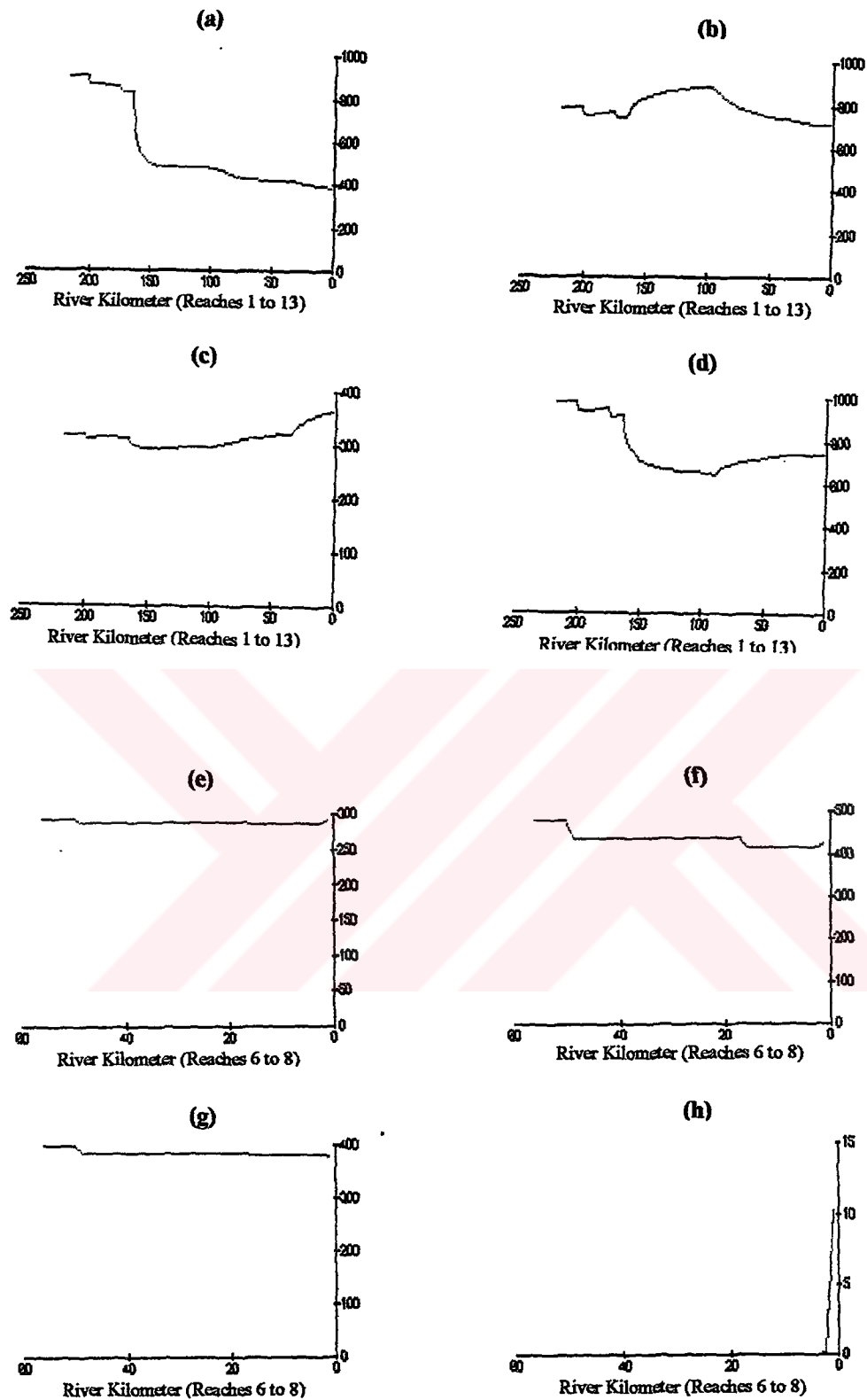


Figure 5.20 EC ($\mu\text{mho/cm}$) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

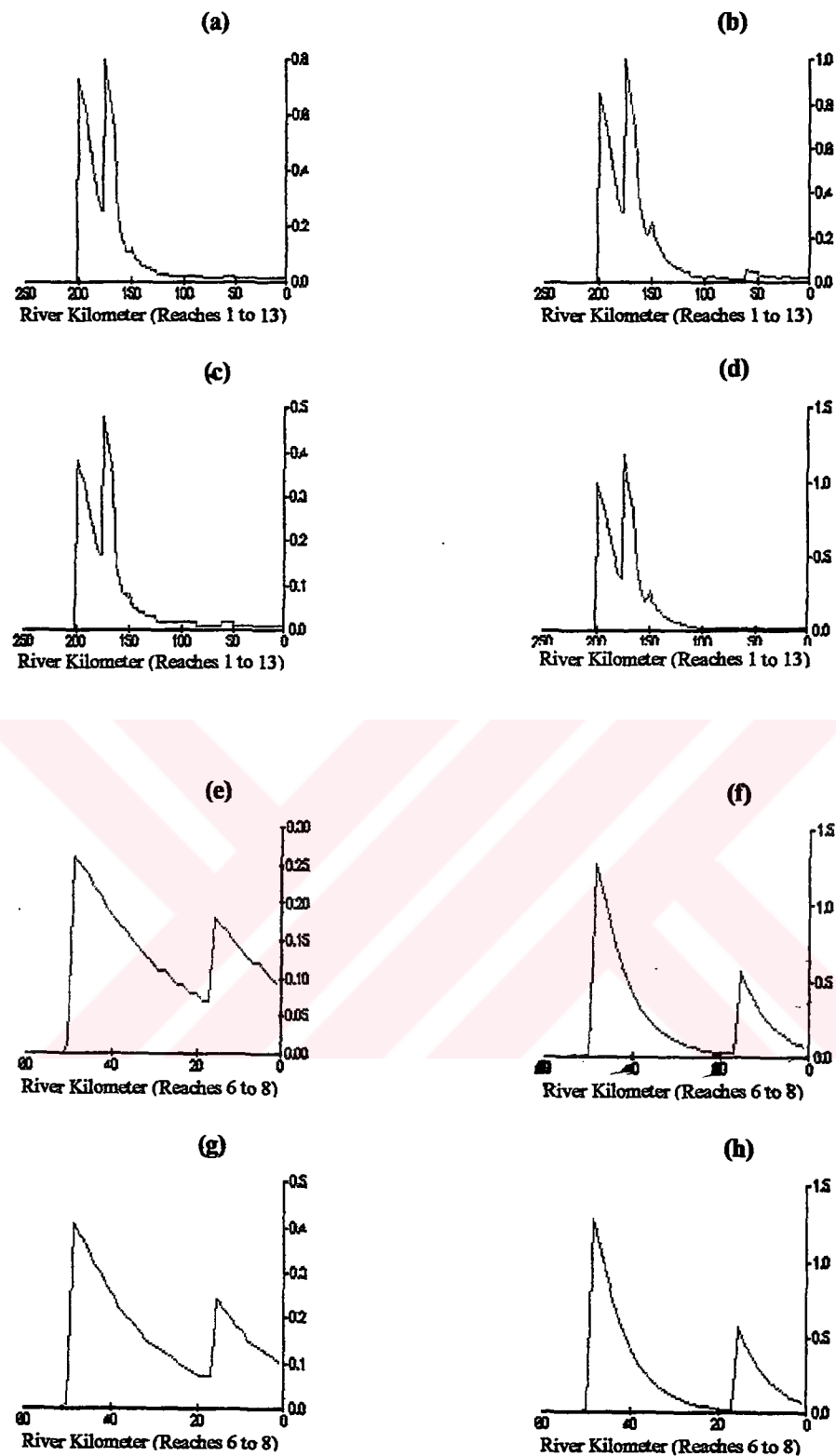


Figure 5.21 Organic Nitrogen (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

It is observed from Fig. 5.22 that $\text{NH}_3\text{-N}$ follows seasonal patterns similar to those of Org-N , namely that there are no major differences between the seasons. On the main stream, summer and fall concentrations are approximately at the same levels. In winter, a high of 1.1 mg/l is observed in contrast to 0.7 mg/l in the spring. The tributary shows the same trends, with slight increases from a maximum of 0.45 mg/l in the winter to 0.7 mg/l in the spring.

On the main stream, $\text{NO}_2\text{-N}$ of Fig. 5.23 shows slight seasonal variations. Basically, winter and spring variations follow a similar pattern, the same is true for the summer and fall seasons. The concentration levels change between seasons with lower values in winter/spring and higher values in the summer/fall season. Similar evaluations can be made for the tributary with respect to seasonal variations of $\text{NO}_2\text{-N}$.

For $\text{NO}_3\text{-N}$ of Fig. 5.24, summer and fall variations are similar but the other seasons show different fluctuations. On the main stream, there is a general increase in $\text{NO}_3\text{-N}$ levels in all seasons except for the spring. On the tributary, winter and spring variations are approximately the same in both pattern and the levels of $\text{NO}_3\text{-N}$. Summer and fall seasons show similar variations although the levels of $\text{NO}_3\text{-N}$ differ slightly.

Org-P of Fig. 5.25 shows the same variations on the main stream as BOD and Org-N . Variation patterns do not change with respect to seasons although there are differences in the levels of Org-P . On the tributary, winter and spring show similar variations. The same is true for summer and fall. These variations show the effects of point load inputs rather than the effects of incremental flows.

Dis-P shows seasonal variations both on the main stream and the tributary as indicated in Fig. 5.26. Similarities exist between winter/spring and summer/fall periods although levels of Dis-P concentrations change between the seasons. The effects of both point loads and incremental flows can be observed in these variations.

Figures 5.27 and 5.28 show that Sum-N and Sum-P follow similar patterns with respect to seasons. These variations are also similar to those of Org-N , Org-P and BOD. Again, summer/fall seasons have the same patterns just as those in the winter/spring periods. This result is true for both the main stream and the tributary.

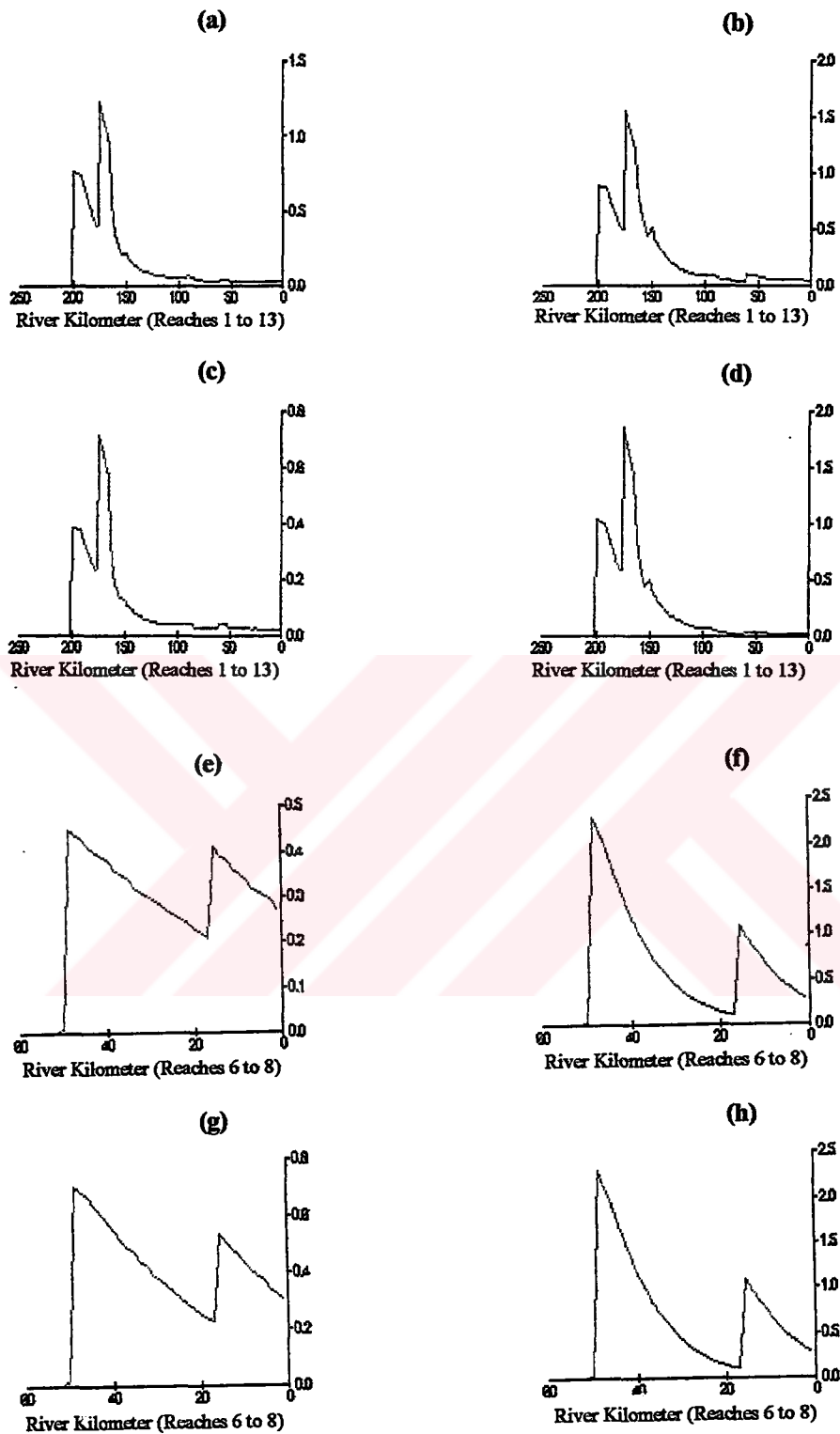


Figure 5.22 Ammonia Nitrogen (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

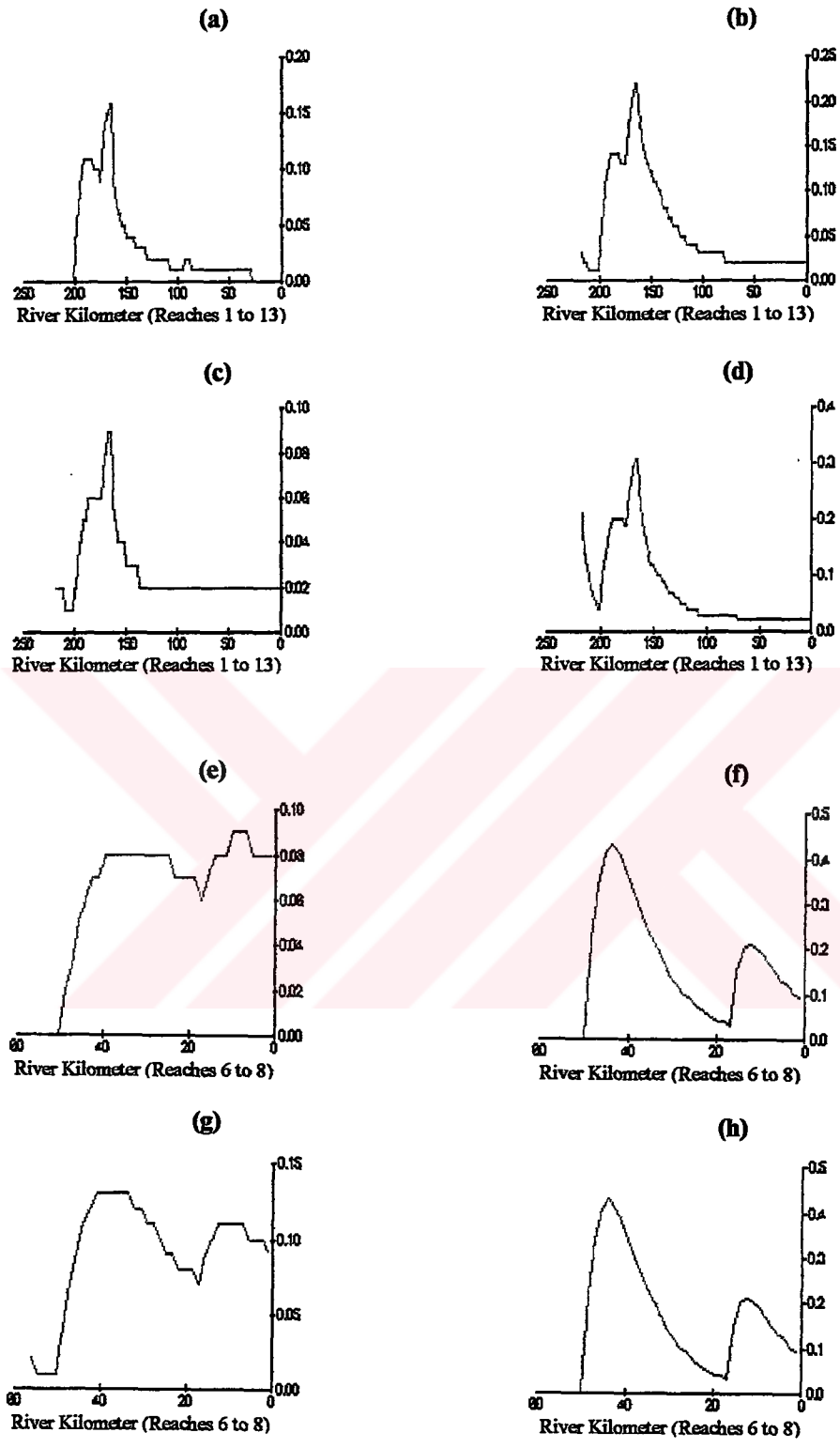


Figure 5.23 Nitrite Nitrogen (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

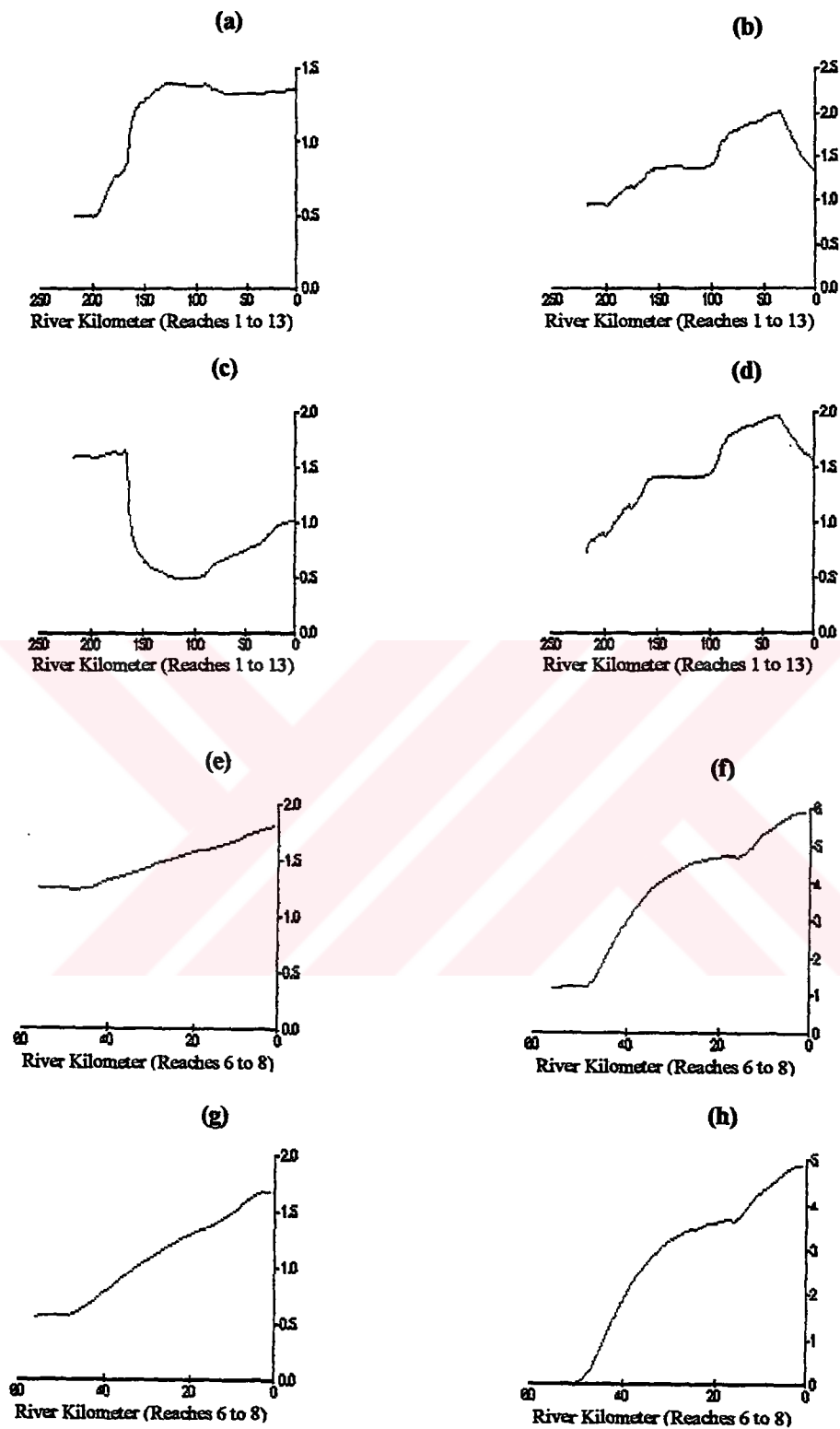


Figure 5.24 Nitrate Nitrogen (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

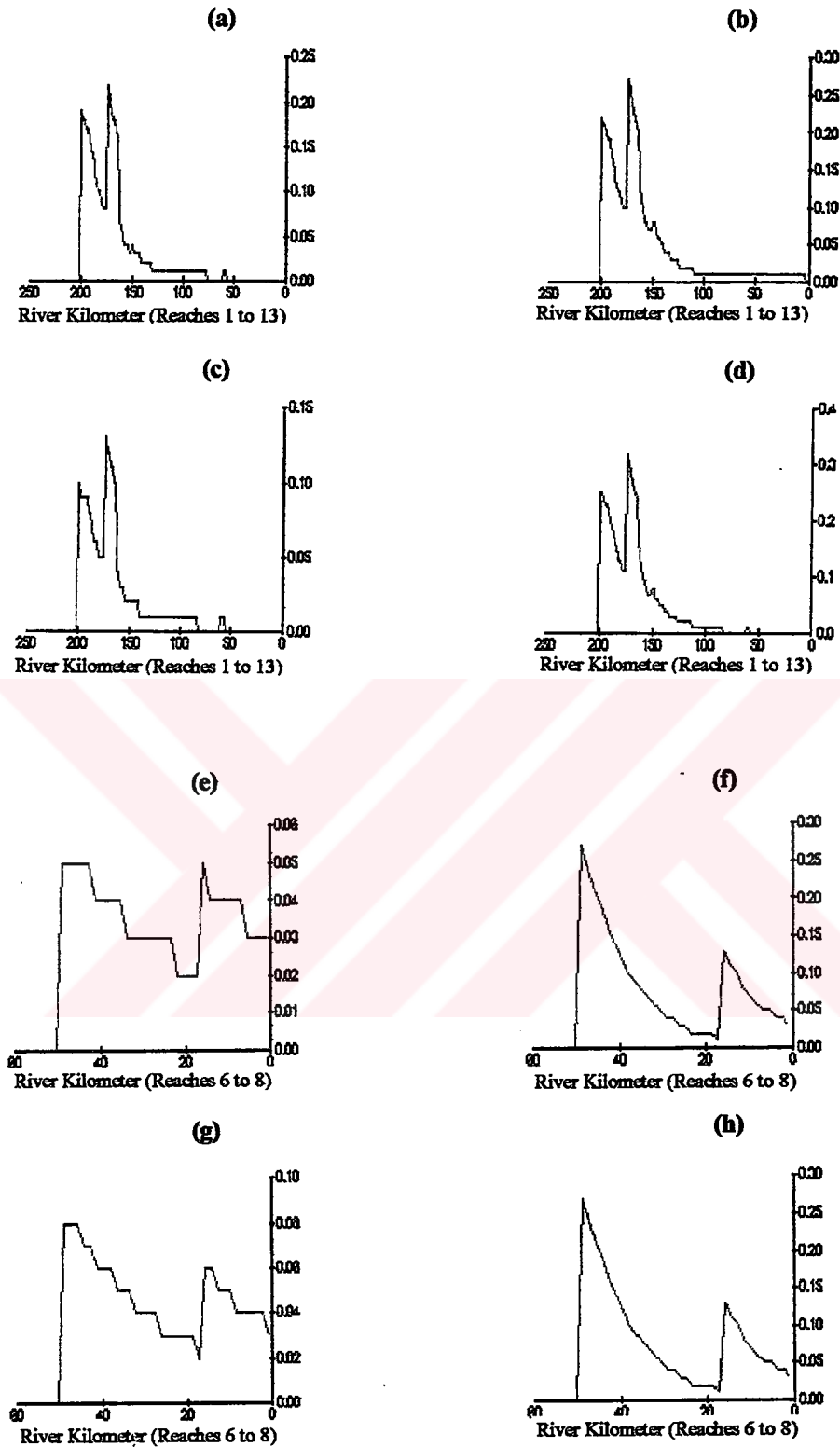


Figure 5.25 Organic Phosphorus (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

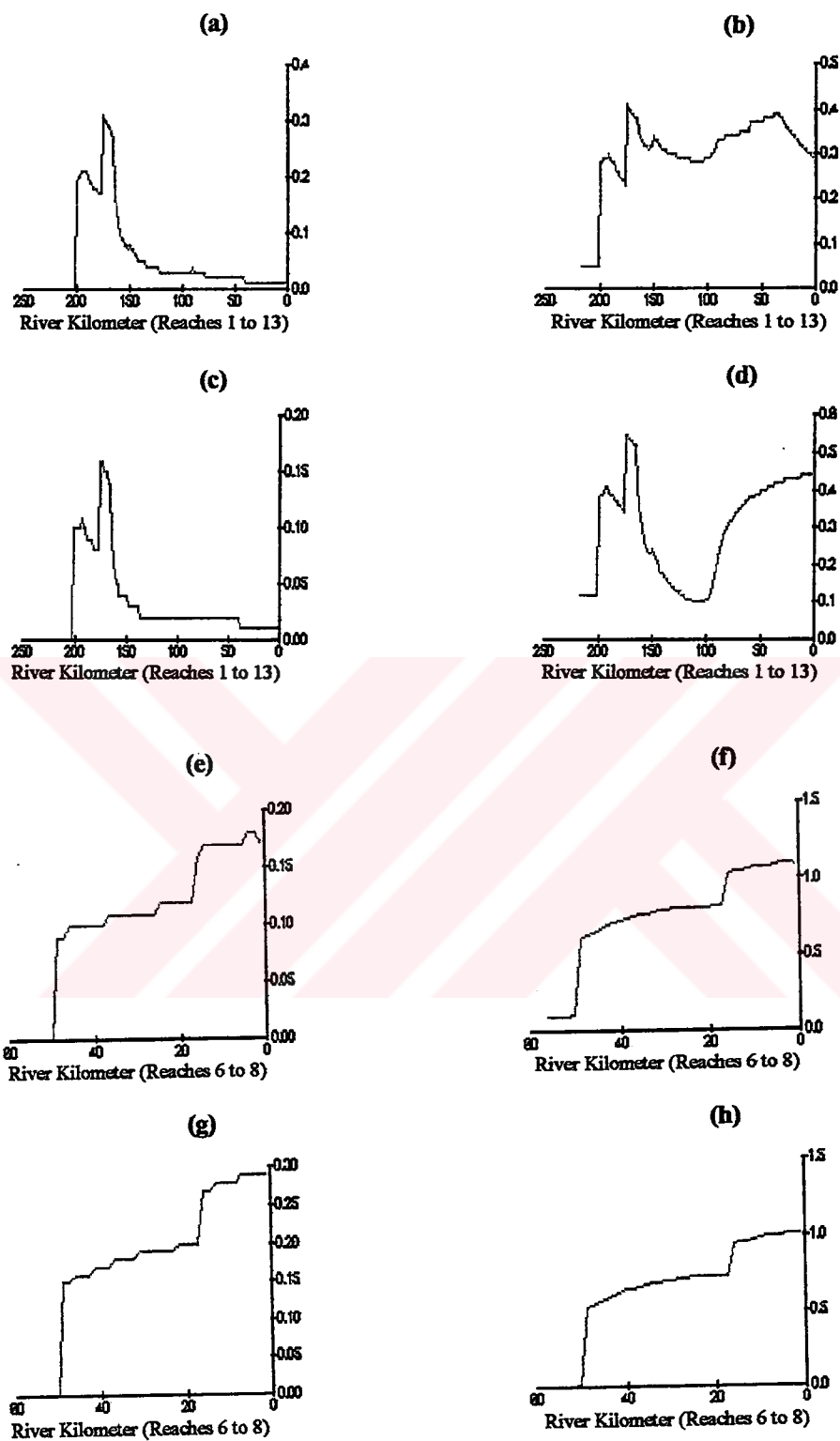


Figure 5.26 Dissolved Phosphorus (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

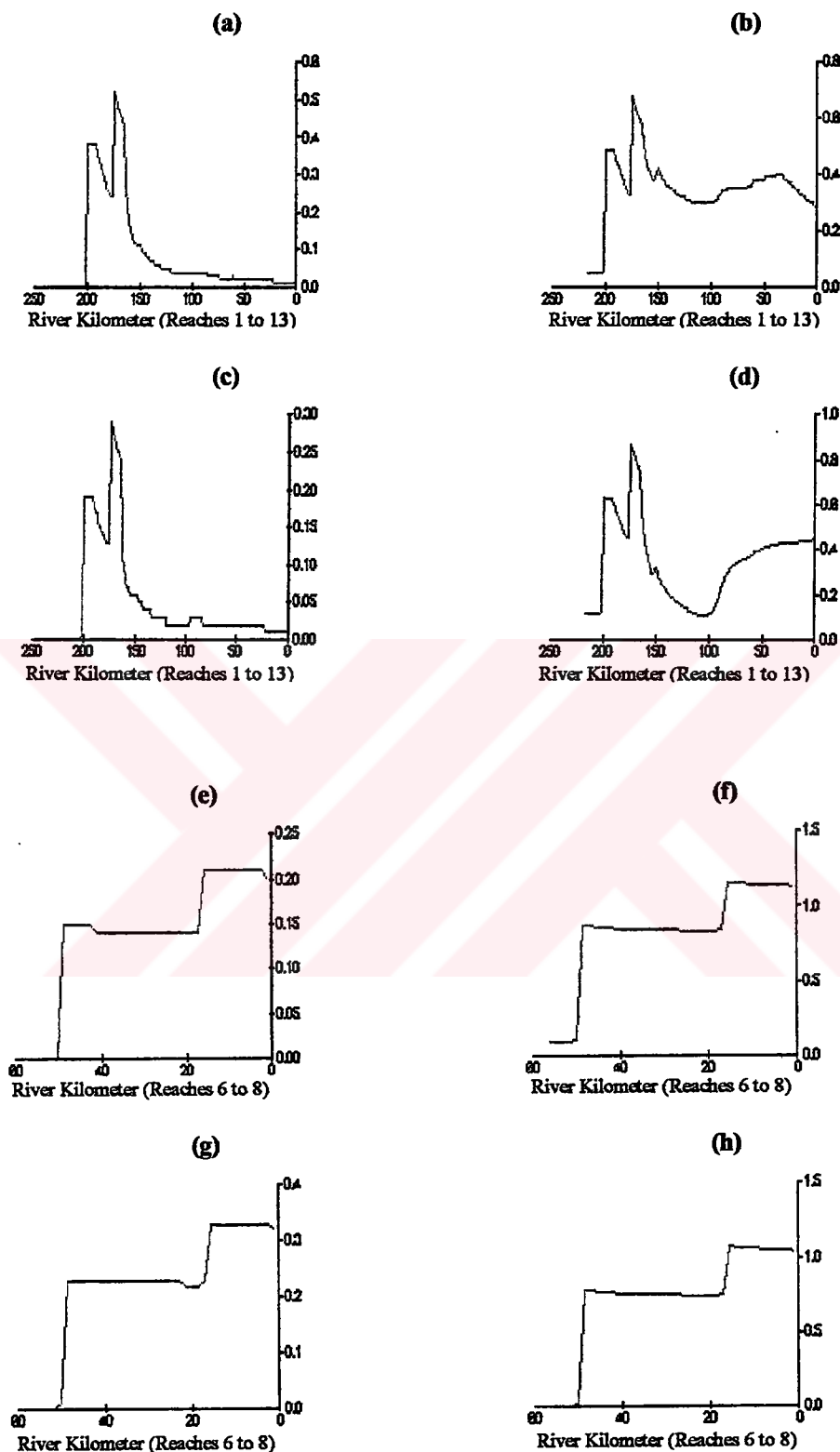


Figure 5.27 Sum-P (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

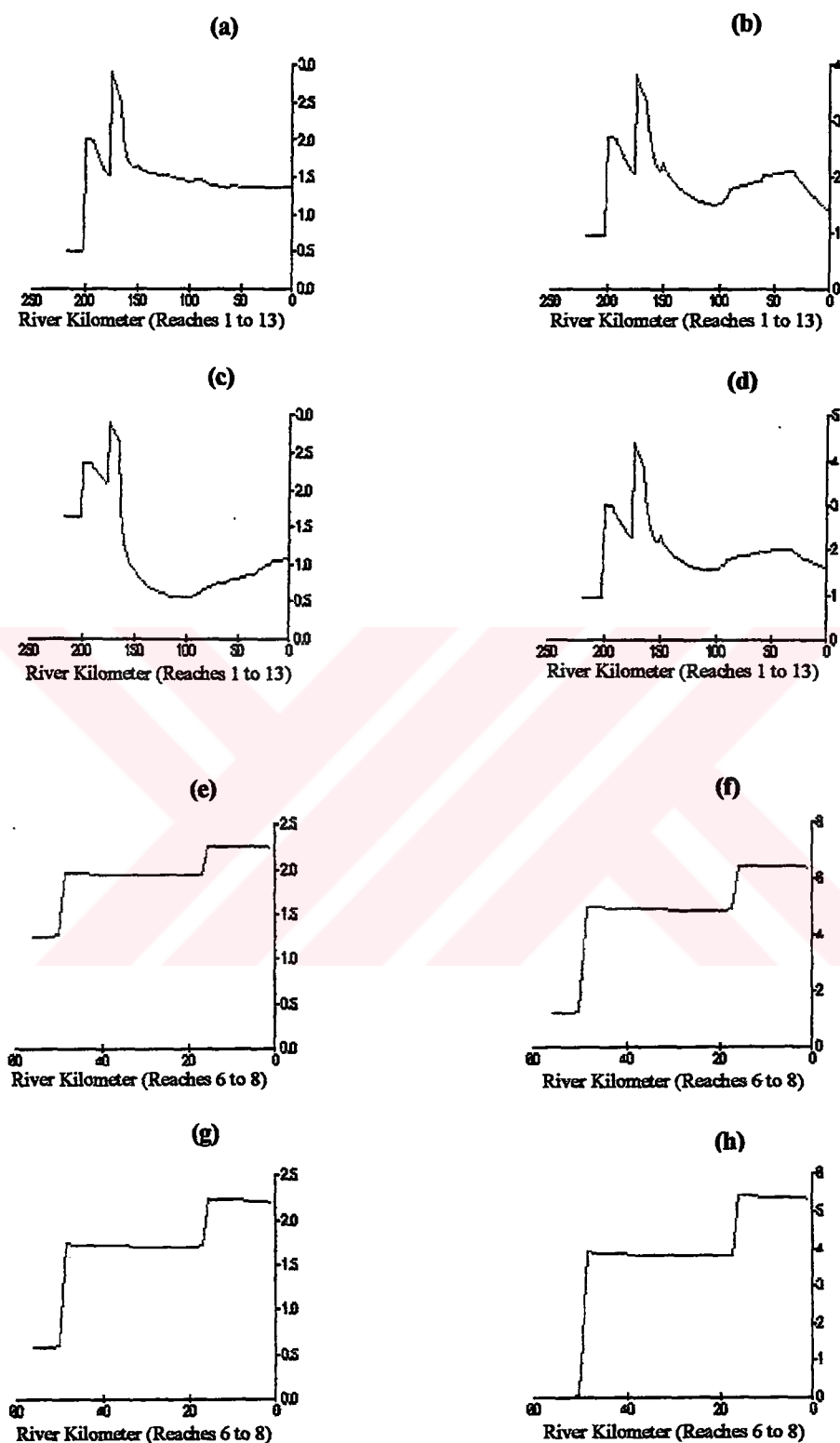


Figure 5.28 Sum-N (mg/l) on the Main Stream; (a) Winter, (b) Summer, (c) Spring, (d) Autumn; and on the Tributary; (e) Winter, (f) Summer, (g) Spring, and (h) Autumn.

CHAPTER SIX

CONCLUSIONS

The objective of the presented study has been to investigate the capabilities and properties of QUAL2E in simulating water quality and then to apply it to a test basin in Turkey.

The study of model features has revealed that QUAL2E is an effective tool to simulate water quality processes in space-time dimensions, thereby making it possible to estimate the contribution of each polluting source to the variability of water quality along the river. Information provided by simulation studies can then constitute inputs to the management model at the final stage. The model can also be effectively integrated to an expert system for the decision-making process.

QUAL2E can be operated as a steady state model to investigate the effects of pollutant loads upon river quality and to identify the magnitude and structure of nonpoint discharges. The model can also be run as a dynamic model to analyze the effects of diurnal variations in meteorological data on water quality. However, dynamic simulation requires real-time monitoring which could not be realized for purposes of this study. Therefore, the study presented gives results only for steady state simulation.

The investigations on the model properties have shown that QUAL2E is highly comprehensive, flexible and able to model a wide spectrum of physical conditions. However, this flexibility may be a disadvantage to the modeler unfamiliar with the structure of the package since several decisions have to be made to adjust this structure to the specific problem investigated.

Unlike some other water quality models, the hardware requirements of QUAL2E are not extensive. Yet, there are some dimensional limitations such as the number of reaches, computational elements, headwater elements, junction elements and point source/withdrawal elements that could be included in the model. Another limitation is that QUAL2E requires uniform lengths of computational elements throughout the reaches. Furthermore, it does not have a separate calibration file but involves only an observed DO file to assist in calibration and verification procedures. Another limitation is that QUAL2E does not include a statistical post processor to evaluate the outputs. Some water quality models do not have these limitations so that they may be superior to QUAL2E in a number of ways (Alpaslan et al., 1994). On the other hand, the QUAL2E-UNCAS module of the model is a significant enhancement to model capabilities since it permits uncertainty and risk analyses for the decision-making process.

With regard to application of the model, the basic problems encountered are related to data requirements. It has been found that, as in any other basin in Turkey, appropriate data that represent the physical conditions in the basin are not adequate. This poses problems first in hydrodynamic identification of the river. Next, other physical characteristics, such as climatological parameters or parameters related to quality characteristics of the basin, could not be based on sufficient data so that in most cases default values of such parameters are used. These data are required to calibrate the model parameters for Gediz basin; however, retrieval of such data requires an extensive data collection program which could not be realized within the framework of this study. Furthermore, the water quality data that could be input the model were found to be adequate only for the year 1983, such that the results of the model run represent the quality conditions of the river as of this period. In addition, no data were available on some tributaries which are highly polluted (e.g. Nif creek). Similarly, sufficient information could not be obtained about industrial wastewater discharges. Another limitation is that simultaneous measurements of water quantity and quality were not available. Due to these data limitations, the results of the application do not realistically represent the case of Gediz. Nevertheless, if appropriate and adequate data can be provided, it will be possible to produce effective simulation of water quality in the basin. It is expected that such applications can be further developed and that QUAL2E can be used as an effective decision-making tool for future management practices in the basin.

The basic purpose of the presented study has been to operate the model so that it can be applied to a real case. In this respect, the study has fulfilled its objectives. The results obtained should not be employed to evaluate current quality conditions in the basin but to identify inadequacies and limitations in data required for future applications of the model.



REFERENCES

- Alpaslan,N., Harmancioğlu, N. B. (1990). Water Quality Monitoring Site Selection. Stuttgart, Proceedings of Seminar, Umweltschutz, German-Turkish-Polish Environmental Engineering Symposium, September 1990, pp. 185-205.
- Alpaslan,N., Harmancioğlu, N. B. (1991). Environmental Decision Models. In: Advances in Water Resources Technology, A. A. Balkema Publishers, pp. 339-347.
- Alpaslan,N., Harmancioğlu, N. B., Özkul, S. (1993). Risk Factors in Assessment of Compliance with Standards. Los Angeles, California, IAWRPC 1993 Conference on Risk, Risk Analysis Procedures and Epidemiological Confirmation, August 1993, 13 p, (Bildiri Pergamon Press tarafından basılan Water Science & Technology adlı seride basılmak üzere kabul edilmiştir).
- Alpaslan,N., Harmancioğlu, N. B., Saner, E. (1994). Proposed Management of the Yeşilirmak River Basin.In: Integrated River Basin Development, (Ed. C. Kirby & W. R. White), John Willey & Sons Ltd., England, pp. 97-107.
- Alpaslan,N., Harmancioğlu, N. B., Saner, E. (1994). Management of the Yeşilirmak Basin to Maximize Fishery Production.In: Advances in Water Resources Technology and Management, (Ed. G.Tsakiris & M. A. Santos), A.A. Balkema, Rotterdam, pp. 343-350.
- Alpaslan,N., Harmancioğlu, N. B., Saner, E., Özkul, S. & Fıstıkoğlu, O. (1995). Maximization of Freshwater Productivity: Case of the Yeşilirmak River Basin in Turkey.Ninth World Productivity Congress, İstanbul, June 4-7.
- Brown, L. C., & Barnwell, T. O. (1987). The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual. Environmental Research Laboratory Office of Research and Development, U. S. Environmental Protection Agency, Athens, Georgia.
- Brown, L. C., & Barnwell, T. O. (1995). The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS User Manual. As computer files.
- Canter, L.W. (1985). River Water Quality Monitoring. Lewis Publishers, Inc.
- DMI (State Meteorological Works), (1996). Meteorological data is obtained from personal communication.

- Donigian, A. S., Imhoff, J. C., & Ambrose, R. B. (1995). Environmental Hydrology. In V. P. Singh (Ed.), Modeling Watershed Water Quality, (pp. 377-426).
- DSI, Water Quality Annuals (1983-1984) (1987). DSI General Directorate Water Supply and Sewerage Department, Ankara.
- EIE, 1983 Water Year Discharges (1986). EIE General Directorate of Electrical Works.
- Environmental Quality. (1970). The first annual report of the Council on Environmental Quality together with the President's Message to Congress, Transmitted to the congress.
- Ergen, S. (1995). Water Quality Modeling of the Orhaneli River, Using the Stream Water Quality Computer Model QUAL2E. Master of Science thesis.
- Fleming, G. (1977). Computer Simulation Techniques in Hydrology. Elsevier Environmental Science Series, U.S.A.
- Ganoulis, J. G. (1994). Engineering Risk Analysis of Water Pollution - Probabilities and Fuzzy Sets. VCH Verlagsgesellschaft mbH, D-69451 Weinheim (Federal Republic of Germany).
- Gordon, S.I. (1985). Computer Models in Environmental Planning. Van Nostrand Reinhold Company, Inc.
- Gündoğdu, V. (1991). Spatial Design of Water Quality Monitoring Networks. Master of science thesis in Environmental Engineering. Dokuz Eylül University, Graduate School of Natural and Applied Sciences, İzmir. (Advisor: N. ALPASLAN)
- Harmancıoğlu, N., Alpaslan, N. (1991). Current Status of Risk and Reliability Assessment in Water Quality Management. Porto Carras, Greece, NATO-ASI on Risk and Reliability in: Water Resources & Environmental Engineering, May 18-28, 17 p.
- Harmancıoğlu, N., Alpaslan, N. (1992). Risk Factors in Water Quality Assessment. In: Managing Water Resources during Global Change. (Ed. R. Herrmann), American Water Resour. Assoc., AWRA Publications, pp. 299-308.
- Harmancıoğlu, N., Alpaslan, N. (1993). Uncertainties in Water Quality Management. In: Environmental Management Geo-water and Engineering Aspects. (Eds. R. N. Chowdhury & M. Sivakumar), Rotterdam, A. A. Balkema Publishers, pp. 703-709.
- Harmancıoğlu, N., Alpaslan, N., Özkul, S., Saner, E., & Fıstıkoğlu, O. (1993). Su kalitesi Bilgisayar Modeli Program Paketleri - Cilt 2: QUAL2E Kullanıcı El Kitabı, İzmir. TÜBİTAK Deniz Bilimleri ve Balıkçılık Araştırma Grubu desteği ile Tarım Köy İşleri Bakanlığı Koruma ve Kontrol Genel Md. ve D.E.Ü. Vakfı İşletmeleri için, Yeşilirmak Havzası Su Kirliliği ve Su Toplama Havzası İçsu Üretim Potansiyelinin Tesbiti adlı ve DEBAG-71/G kod no.'lu araştırma projesi raporu, 119 s., 1993.

- Harmancıoğlu, N., Alpaslan, N., Özkul, S., Saner, E., & Fıstıkoğlu, O. (1993)., Su kalitesi Bilgisayar Modeli Program Paketleri - Cilt 1. Genel Esaslar. İzmir. TÜBİTAK Deniz Bilimleri ve Balıkçılık Araştırma Grubu desteği ile Tarım Köy İşleri Bakanlığı Koruma ve Kontrol Genel Md. ve D.E.Ü. Vakfı İşletmeleri için, Yeşilirmak Havzası Su Kirliliği ve Su Toplama Havzası İçsu Üretim Potansiyelinin Tesbiti adlı ve DEBAG-71/G kod no.lu araştırma projesi raporu, 119 s., 1993.
- Harmancıoğlu, N., Alpaslan, N., Özkul, S., Saner, E., & Fıstıkoğlu, O. (1994). Application of Simulation Models in Integrated River Basin Management. Fifth International Conference ENVIROSOFT 94, San Fransisco, USA, November 16-18, 8 p.
- Manisa Valiliği Çevre İl Müdürlüğü (1995). Gediz Havzası Kirliliği.
- McKinney, R.E. (1962). Microbiology for Sanitary Engineers. McGraw-Hill Series in Sanitary Science and Water Resources Engineering.
- Özer, A., Alpaslan, N. (1985). Çevre Etki Değerlendirilmesi ve Matematiksel Modeller. "Çevre'85" Çevresel Etki Değerlendirilmesi, İzmir
- Özmenek, M. A. (1996). Development of Water Quality Management Model for Yeşilirmak Basin. (Doctor of Philosophy Thesis), METU, Ankara.
- Saner, E., Alpaslan, N., Harmancıoğlu, N. B. (1995). Maximizing the Productivity of Environmental Management Practices, Ninth World Productivity Congress, İstanbul, June 4-7.
- Sawyer, C.N. (1978). Chemistry for Environmental Engineering. McGraw-Hill Book Company.
- Shen, H.W. (1977). Modeling of Rivers. A Wiley-Interscience Publication, John Wiley and Sons, Colorado State University.
- Tchobanoglous, G., & Schroeder, E.D. (1985). Water Quality - Characteristics, Modeling, Modification. Addison - Wesley Publishing Company.
- Tchobanoglous, G., & Burton, F. L.(Eds.). (1991). Wastewater Engineering-Treatment, Disposal, and Reuse". Metcalf & Eddy, Inc., McGraw-Hill International Editions.
- Uslu, O., Çelebi, S., Türkman, A., & Şengül, F. (1983). Çevresel Modelleme Üzerine. "Çevre'83" II. Ulusal Çevre Mühendisliği Sempozyumu, İzmir.
- Uslu, O., Harmancıoğlu, N., & Alpaslan, N. (1984). Çevresel Karar Modelleri. "Çevre'84" V. Türk-Alman Çevre Mühendisliği Sempozyumu, İzmir.
- Uslu, O., & Türkman, A. (1987). Water Pollution and Control. Prime Ministry General Directorate of Environment Publications Educational Series I.
- Wrobel, L. C., & Brebbia, C. A. (1991). Water Pollution: Modeling, Measuring and Prediction. Computational Mechanics Publications.

Appendix A

**Global Kinetics Parameters
and
Temperature Correction Factors
Literature Review**

A.1 GLOBAL KINETICS PARAMETERS

i. Oxygen Uptake by NH₃ (NH₃OXYUP) Oxidation and NO₂ Oxidation (NO₂OXYUP)

The cause of oxygen uptake in waters is the metabolism of organic materials by bacteria. In a closed system the three variables - organic concentration, bacterial mass and dissolved oxygen consumed - are very important.

Oxygen uptake rate (OUR) can be taken as a measure of the biological activity. High oxygen uptake rates indicate high biological activity, low values indicate low biological activity. Results are reported as (mg O₂ / L . min) or (mg O₂ / L . h) (Tchobanoglous & Schroeder, 1985).

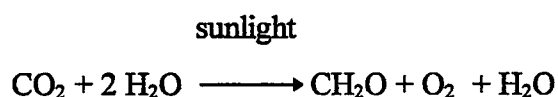
In the model, the range of oxygen uptake by NH₃ oxidation is 3-4 mg O /mg N and the default value is 3.43 mg O /mg N. This parameter has no dependence with temperature.

The range of oxygen uptake by NO₂ oxidation in the model is 1.0-1.14 mg O /mg N and the default value is 1.14 mg O /mg N. This parameter has also not temperature dependence.

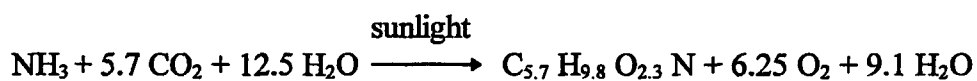
ii. Oxygen Production (AGYOXYPR) and Oxygen Uptake by Algae (AGYOXYUP)

Algae are that it includes all microscopic plants carrying out true photosynthesis. Algae are autotrophic, photosynthetic and contain chlorophyll. Oxygen is produced during the photosynthesis process (McKinney, 1962).

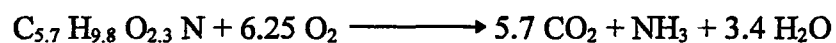
In the presence of sunlight the algae convert the inorganic materials in the water into organic matter in the form of protoplasm.



The over-all equation for the growth of algae can be expressed by the following equation (McKinney, 1962);



In the absence of sunlight some of the algae are able to carry on chemosynthetic metabolism like bacteria. In doing so the algae require oxygen for oxidation. The endogenous metabolism equation is as follows (McKinney, 1962):



The oxygen released by the algae through the process of photosynthesis is used by the bacteria in the anaerobic degradation of organic matter. The nutrients and carbon dioxide released in this degradation are used by algae.

Algae can be great nuisance in surface waters because when conditions are available, they will rapidly reproduce and cover streams, lakes and reservoirs. These are large floating colonies called blooms. Algal blooms are usually characteristics of what is called a eutrophic lake or a lake with a high content of the compounds needed for biological growth.

The presence of algae affects the value of water for water supply because they often cause taste and odor problems. Algae can also alter the value of surface waters for the growth of certain kinds of fish and for other uses (McKinney, 1962).

In the model, oxygen production per unit of algae growth is given in the range of 1.4-1.8 mg O / mg A and as a default value, 1.6 mg O / mg A. Oxygen uptake per unit of algae respiration is given in the range of 1.6-2.3 mg O / mg A and as a default value 2.0 mg O / mg A.

iii. Nitrogen(AGYNCON) and Phosphorus Content of Algae (AGYPCON)

The critical element in algae growth is phosphorus. Nitrogen is critical with many algae, but the blue-green algae have the ability to fix atmospheric nitrogen in the absence of soluble nitrogen. The composition of algae ($\text{C}_5\text{H}_8\text{O}_2\text{N}$) can be given in Table A-1.

Table A-1 The Composition of Algae (Sawyer, 1978).

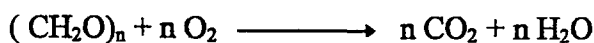
Element	Concentration, %
C	49
H	6.0
O	27
N	11
P	2.5
S	0.7
Na	0.7
K	0.5
Ca	0.7
Mg	0.5
Fe	0.1

In most natural waters the phosphorus content is very low, and algae growth is limited. But in farming areas where the runoff of surface waters carries away the fertilizers, the phosphorus content becomes quite high and algae growth is larger (Sawyer, 1978).

In the model, nitrogen fraction of algae biomass is about 0.08 to 0.09, and phosphorus fraction is about 0.012-0.015. The default values for nitrogen and phosphorus are respectively 0.085 and 0.014.

iv. Algae Maximum Growth Rate (AGYGROMX) and Respiration Rate(AGYRESPR)

Respiration occurs in the presence of sunlight. The amount of oxygen released usually exceeds the amount used during daylight. Respiration is defined with following equation (McKinney, 1962).



In the model, the maximum specific growth rate has a range of 1-3 day⁻¹ and the algae respiration rate has a range of 0.05-0.5 day⁻¹. The respiration value of 0.05 is for clean streams, while 0.2 is used where N_e , effective nitrogen concentration and P_2 , inorganic or dissolved phosphorus concentrations are greater than twice the half saturation constants.

v. Nitrogen (NHALFSAT) and Phosphorus Half Saturation Constants (PHALFSAT)

For the reaction; $a A \longrightarrow b B$, typical saturation-rate function can be written as follows:

$$r = \frac{k [A]}{K + [A]} \quad (A-1)$$

where;

- r : rate of reaction, mole/L
 k : reaction rate constant, mole/L
 $[A]$: concentration of reactant A, mole/L
 K : half saturation constant, mole/L

Often saturation-rate functions are more complex than the above equation. Following equation often encountered in the modeling of environmental engineering systems (Sawyer, 1978).

$$r = \frac{k [A][B]}{K + [A]} \quad (A-2)$$

In the model, the values for nitrogen range from 0.01 to 0.3 mg/l and for phosphorus the values range from 0.001 to 0.05 mg/l. The default values are for nitrogen and phosphorus are 0.2 and .0.04 mg/l respectively.

vi. Linear (λ_1) (AGYEXTLN) and Non-linear (λ_2) Algal Selfshading Light Extinction Coefficient (AGYEXTNL)

General light extinction equation is (Brown & Barnwell, 1987);

$$\lambda = \lambda_0 + \lambda_1 \cdot \alpha_0 \cdot A + \lambda_2 (\alpha_0 \cdot A)^{2/3} \quad (A-3)$$

where;

λ_0 : Non-algal light extinction coefficient, ft^{-1}

λ : total light extinction coefficient

A : algae biomass concentration, mg A / l

α_0 : chlorophyll a to algae biomass ratio, $\mu\text{g Chl a / mg A}$

$$\lambda_1 : \frac{1/\text{ft}}{\mu\text{g Chl a / l}}$$

$$\lambda_2 : \frac{1/\text{ft}}{(\mu\text{g Chl a / l})^{2/3}}$$

There are three possibilities with appropriate selection of the values of λ_0 , λ_1 , λ_2 :

- | | |
|---|---------------------------|
| $\lambda_1 = \lambda_2 = 0$ | No self shading |
| $\lambda_1 \neq 0, \lambda_2 = 0$ | Linear algal self shading |
| $\lambda_1 = 0.0088, \lambda_2 = 0.054$ | Non-linear self shading |

In the model, the range of λ_1 value is 0.002-0.02 $(1/\text{ft})/(\mu\text{g Chl a / l})$ and for λ_2 is 0 - 0.0165 $(1/\text{ft})/(\mu\text{g Chl a / l})^{2/3}$. The default values used by the model are respectively 0.00075 and 0.0 (Brown & Barnwell, 1987).

vii. Solar Light Function Option

This option is used for computing the effects of light attenuation on the algal growth rate and the light saturation coefficient. Model has three different solar light function options; and has three different light saturation coefficient related to the each function (Brown & Barnwell, 1987).

<u>Light function option</u>	<u>Light Saturation Coefficient</u>
1. Half Saturation	Half saturation coefficient
2. Smith's function	Light intensity corresponding to 71% of maximum growth rate
3. Steele's function	Saturation light intensity

Default values are option 1.0 and light saturation coefficient is 0.11.

viii. Light Averaging Option (LAVOPT)

This option allows the user to specify the manner in which the light attenuation factor is computed, from the available values of solar radiation.

Option	Description
1	FL is computed from one daily average solar radiation value calculated in the steady-state temperature subroutine.
2	FL is computed from one daily average solar radiation.
3	FL is obtained by averaging the 24 hourly data.

FL is the algal growth limiting effects of light.

In the case of algae simulation, Options 1 or 3 must be selected. In dynamic algae simulations, Option 3 is used unless temperature is not simulated, in which case solar radiation data are read in with the local climatology data (Brown & Barnwell, 1987).

ix. Light Averaging Factor (LAVGFACT)

There is a range of 0.85 and 1.0, for this parameter.

x. Number of Daylight Hours (NUMBDLH), Total Daily Radiation (TDYSOLAR)

These two parameters are used if light averaging Options 2 or 4 are specified for the simulation. The default values for NUMBDLH and TDYSOLAR are respectively 14.0 and 1300.0 (Brown & Barnwell, 1987).

xi. Light-nutrient Option for Computing the Algal Growth Rate (LGROPT)

The light-nutrient interactions for computing algae growth rate are shown as follows (Brown & Barnwell, 1987):

Option	Description
1	Multiplicative : $FL * FN * FP$
2	Limiting Nutrient : $FL * [\min (FN, FP)]$
3	Harmonic Mean : $(FL * 2) / [(1/FN) + (1/FP)]$

FL : algal growth limiting effects of light
FN : algal growth limiting effects of nitrogen
FP : algal growth limiting effects of phosphorus

In the model, the default value is 2.0 .

xii. The Algal Preference Factor for Ammonia (APREFNH3)

This parameter defines the relative preference of algae for ammonia and nitrate nitrogen. The range is from 0.0 to 1.0 .

Algal preference factor for ammonia	Interpretation
0.0	Algae will use only nitrate for growth.
0.5	Algae will have equal preference for ammonia and nitrate.
1.0	Algae will use only ammonia for growth.

Default value is 0.9 .

xiii. Factor for Converting the Solar Radiation value from the Heat Balance to the Solar Radiation value Appropriate for the Algae Simulation (A/TFACT)

This parameter is required only in steady-state simulations when light averaging options 1 or 3 are selected. The value of this fraction ranges between 0.0 and 1.0 . Typically the value of this fraction is about 0.45 .

xiv. The Value of the First Order Nitrification Inhibition Coefficient (NHIBFACT)

This value is determined as KNITRF in the following equation:

$$\text{CORDO} = 1.0 - \exp (-\text{KNITRF} * \text{DO}) \quad (\text{A-4})$$

where;

DO : dissolved oxygen concentration, mg/l

CORDO : correction factor applied to ammonia and nitrite oxidation rate coefficients

(Brown et al., 1987)

A.2 TEMPERATURE CORRECTION FACTORS

i. Reaeration Rate Coefficient

“Reaeration” term is used to describe the atmospheric adsorption of oxygen. The rate of atmospheric reaeration is proportional to the dissolved-oxygen deficiency. The rate of aeration r_R can be defined as follows:

$$r_R = k_2 (C_S - C_{O_2}) \quad (\text{A-5})$$

where;

r_R : rate of aeration, $\text{g/m}^3 \cdot \text{d}$

k_2 : reaeration rate coefficient, d^{-1}

C_S : dissolved-oxygen saturation concentration, g/m^3

C_{O_2} : dissolved-oxygen concentration, g/m^3

The reaeration rate coefficient can be estimated by determining the characteristics of the stream and using one of the many empirical formulas. One of those formulas is the generalized formula proposed for natural streams;

$$k_2 = \frac{294 (D_L * u)^{1/2}}{H^{3/2}} \quad (\text{A-6})$$

where;

D_L : coefficient of molecular diffusion for oxygen, m^2/d

u : mean stream velocity, m/s

H : average depth of flow; m

Typical values of the reaeration rate coefficients are given in Table 2.

Table A-2 Typical values of reaeration rate coefficient (Metcalf & Eddy, 1991).

Water Body	Ranges of k_2 at $20^\circ C$, d^{-1}
Small ponds and backwaters	0.10-0.23
Sluggish streams and large lakes	0.23-0.35
Large streams of low velocity	0.35-0.46
Large streams of normal velocity	0.46-0.69
Swift streams	0.69-1.15
Rapids and waterfalls	> 1.15

In the model, reaeration rate coefficient value ranges from 1.0 to 1.1 d^{-1} . The default value is 1.024 d^{-1} .

ii. Sediment Oxygen Demand (SOD) Uptake Rate Coefficient

The solids discharged with treated wastewater are partly organic. Upon settling to the bottom, they decompose anaerobically as well as aerobically, depending on conditions. The oxygen consumed in aerobic decomposition represents another dissolved-oxygen sink for the water body. For a control volume in contact with the bottom, the rate of dissolved-oxygen depletion due to sediment oxygen demand is given by (Metcalf & Eddy, 1991):

$$r_s = k_s / H \quad (A-7)$$

where;

r_s : rate of oxygen consumption due to SOD per unit time per unit volume of water

k_s : sediment oxygen uptake rate

H : depth of control volume

The major factors affecting k_s (See Table A-3) are the organic content of the sediments, temperature, dissolved-oxygen at the sediment-water interface, makeup of the biological community and current speed.

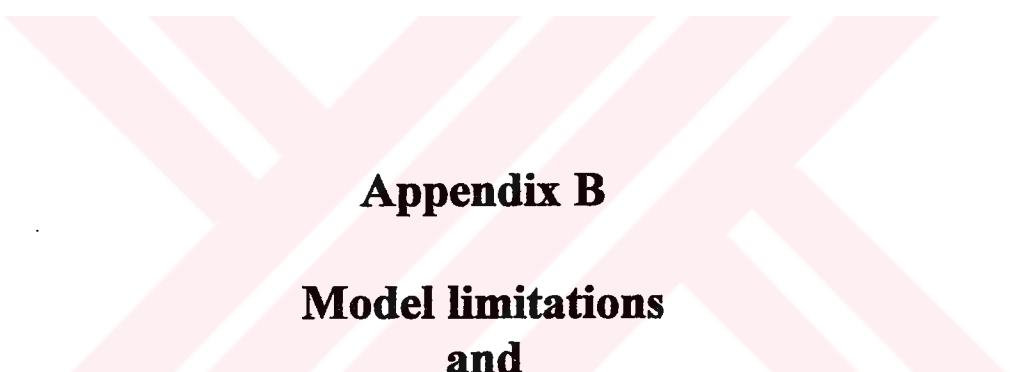
Table A-3 k_s values in different conditions (Metcalf et al., 1991).

Condition	k_s value, g/ft ² .d (g/m ² .d)
Vicinity of municipal wastewater outfalls	0.2-1.0 (2-10)
Downstream are as of municipal outfalls	0.1-0.2 (1-2)
Sandy bottom	0.02-0.1 (0.2-1.0)
Mineral soils	0.005-0.01 (0.05-0.1)

In the model, this value has a range of between 1.0 to 1.1 g/ft².d and has a default value of 1.060 g/ft².d .

The literature values and the values in the model adapt to each other.





Appendix B

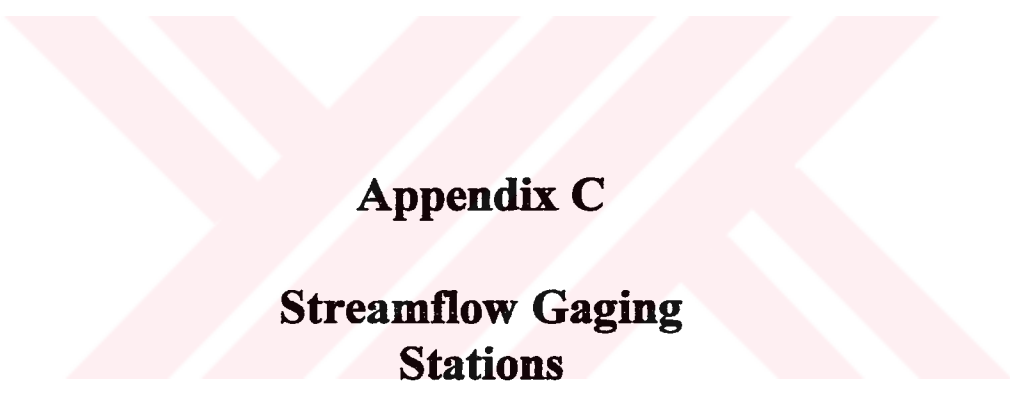
Model limitations and default values

Model limitations and the default values can be given as following tables.

Parameter	Minimum	Maximum	Default
CONTROL DATA			
Time step (h)	0.0	none	0.0
5D-ULT BOD Conversion Coefficient	none	none	0.23
Maximum route (h)	0.0	none	0.0
Time for RPT2 (h)	0.0	none	0.0
Maximum iterations	1.0	none	30.0
Latitude of basin (°C)	0.0	90.0	34.0
Longitude of basin (°C)	0.0	180.0	85.0
Standard meridian (°C)	0.0	180.0	75.0
Start day	1.0	366.0	180.0
Evaporation coefficient (AE)	4.9E-6	0.00006199999	9.4E-6
Evaporation coefficient (BE)	3.2E-6	5.49999E-6	3.2E-6
Elevation of basin (m)	-120.0	3650.0	305.0
Dust attenuation coefficient	0.05	0.15	0.06
ALGAL, NITROGEN AND PHOSPHORUS PARAMETERS			
NH3OXYUP	3.0	3.5	3.43
NO2OXYUP	1.0	1.2	1.14
AGYOXYPR	1.4	1.8	1.6
AGYOXYUP	1.6	2.3	2.0
AGYNCON	0.08	0.09	0.085
AGYPCON	0.012	0.015	0.014
AGYGROMX	1.0	3.0	2.5
AGYRESPR	0.05	0.5	0.05
NHALFSAT	0.02	0.4	0.2
PHALFSAT	0.002	0.1	0.04
AGYEXTLN	0.0	0.003	0.0007499999
AGYEXTNL	0.0	0.003	0.0
LFNOPTN	1.0	3.0	1.0
LSATCOEF	0.0	0.04	0.03
DIURNOPT	1.0	4.0	2.0
LAVGFACT	0.85	1.0	0.92
NUMBDLH	4.0	18.0	14.0
TDYSOLAR	0.0	400.0	350.0
AGYGROPT	1.0	3.0	2.0
APREFNH3	0.1	0.9	0.9
A/TFACT	0.4	0.5	0.44
NHIBFACT	0.0	10.0	10.0
THETA VALUES			
TC/BODDC	1.0	1.1	1.047
TC/BODST	1.0	1.1	1.024
TC/REAER	1.0	1.1	1.024
TC/SOD	1.0	1.1	1.060
TC/NH2DC	1.0	1.1	1.047
TC/NH2ST	1.0	1.1	1.024
TC/NH3DC	1.0	1.1	1.083
TC/NH3SC	1.0	1.1	1.074
TC/NO2DC	1.0	1.1	1.047
TC/PRGDC	1.0	1.1	1.047
TC/PRGST	1.0	1.1	1.024

THETA VALUES (Continued)			
TC/PO4SC	1.0	1.1	1.074
TC/ALGRO	1.0	1.1	1.047
TC/ALRES	1.0	1.1	1.047
TC/ALSET	1.0	1.1	1.024
TC/CLIDC	1.0	1.1	1.047
TC/ANCDC	1.0	1.1	1.0
TC/ANCST	1.0	1.1	1.024
TC/ANCSC	1.0	1.1	1.0
REACH IDENTIFICATION DATA			
Reach order	0.0	50.0	none
Begin location (km)	0.0	none	none
End location (km)	0.0	none	0.0
FLOW AUGMENTATION DATA			
Number of available sources	0.0	100.0	0.0
Target level (mg/l)	0.0	15.0	5.0
Order of available sources	0.0	100.0	0.0
COMPUTATIONAL ELEMENTS FLAGS			
Number of elements	1.0	20.0	none
Comp. elements flags	0.0	7.0	0.0
HYDRAULIC DATA			
DISPSN-K	6.0	6000.0	60.0
COEFQV-A (m/s)	0.0	none	0.0
EXPOQV-B (m/s)	0.0	1.0	0.0
COEFQH-C (m)	0.0	none	0.0
EXPOQH-D (m)	0.0	1.0	0.0
MANNINGS	0.001	0.05	0.0
TRAP-SS1	0.0	1000.0	0.0
TRAP-SS2	0.0	1000.0	0.0
TRAP-WTH	0.0	none	0.0
TRAP-SLP	0.0	1.0	0.0
TEMPERATURE/LOCAL CLIMATOLOGICAL DATA			
ELEVATIN (m)	-120.0	3650.0	305.0
DUSTATTN	0.01	0.15	0.06
CLOUD	0.0	1.0	0.0
DRYBULB (°C)	2.0	55.0	20.0
WETBULB (°C)	2.0	55.0	15.0
ATMPRES (mbar)	900.0	1100.0	1017.0
WINDVEL (m/s)	0.0	36.0	0.0
BOD/DO COEFFICIENTS			
BOD DECA	0.0	10.0	0.0
BOD SETT	0.0	10.0	0.0
SOD RATE	0.0	10.0	0.0
K2-OPT1	0.0	100.0	0.0
N AND P COEFFICIENTS			
NH2 DECA	0.0	10.0	0.0
NH2 SETT	0.0	10.0	0.0
NH3 DECA	0.0	10.0	0.0
NH3 SRCE	0.0	none	0.0
NO2 DECA	0.0	10.0	2.0
PORG DECA	0.0	10.0	0.0
PORG SETT	0.0	none	0.0
DISP SRC	0.0	none	0.0

ALGAE COEFFICIENTS			
CHLA/ART	1.0	100.0	10.0
ALG SETT	0.0	1.0	1.0
LTEXTNCO	0.0	3.0	0.0
COLI DEC	0.0	24.0	0.0
ANC DECA	0.0	none	0.0
ANC SETT	0.0	none	0.0
ANC SRCE	0.0	none	0.0
INITIAL CONDITIONS			
Temperature (°C)	2.0	55.0	21.0
DO (mg/l)	0.0	15.0	0.0
BOD (mg/l)	0.0	1000.0	0.0
Cons 1,2,3	0.0	none	0.0
ANC	0.0	none	0.0
Coliform (no/100 ml)	0.0	none	0.0
Chl-a (µg/l)	0.0	none	0.0
Org-N (mg/l)	0.0	none	0.0
NH3/N (mg/l)	0.0	none	0.0
NO2-N (mg/l)	0.0	none	0.0
NO3-N (mg/l)	0.0	none	0.0
Org-P (mg/l)	0.0	none	0.0
Dis-P (mg/l)	0.0	none	0.0
INCREMENTAL FLOW			
INCRFLOW	none	none	0.0
The limits for other parameters are the same with Initial Conditions' parameters.			
STREAM JUNCTION DATA			
Number of element upstream	1.0	100.0	0.0
Number of element downstream	1.0	100.0	0.0
Number of element on tributary	1.0	100.0	0.0
HEADWATER DATA			
HWTRFLOW	0.0	none	0.0
The limits for other parameters are the same with Initial Conditions' parameters.			
POINT LOAD/WITHDRAWAL DATA			
PTLDTFCT	0.0	1.0	0.0
PTLDFLOW	none	none	0.0
The limits for other parameters are the same with Initial Conditions' parameters.			
DAM REAERATION COEFFICIENTS			
Element number below dam	1.0	20.0	none
DAMACOF	0.5	2.0	1.0
DAMBCOF	0.01	1.5	1.0
DAMSFRAC	0.0	1.0	0.0
Height of dam (m)	0.0	none	0.0
DOWNSTREAM BOUNDARY 1/2			
The limits for other parameters are the same with Initial Conditions' parameters.			
LOCAL CLIMATOLOGICAL DATA			
Cloud cover	0.0	1.0	0.0
Dry bulb air temperature (°C)	1.0	38.0	15.0
Wet bulb air temperature (°C)	1.0	38.0	15.0
Barometric pressure (mbar)	900.0	1100.0	1017.0
Wind speed (m/s)	0.0	36.0	0.0
DO/BOD PLOT DATA			
Number of plots desired	1.0	5.0	1.0
Number of starting reach number	1.0	13.0	1.0



Appendix C

Streamflow Gaging Stations Data Sets

5 - GEDİZ HAVZASI
509 - MEDAR ÇAYI - KAYALIOĞLU

YERİ : (27° 46' 07" D - 38° 53' 26" K) Manisa'nın Akhisar ilçesine 7 Km. mesafedeki demiryolu köprüsü üzerindedir.

YAĞIŞ ALANI : 901.6 Km²

YAKLAŞIK KOT : 77 m.

GÖZLEM SÜRESİ : 10.Ekim.1951 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 3.654 m³/sn. (22 yıllık) 1983 Su yılında 1.466 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 52.9 m³/sn. (15.1.1983)

1983 Su yılında en az akım : 0.234 " (19.8.1983)

Gözlem süresinde en çok akım : 433. " (15.12.1981)

Gözlem süresinde en az akım : 0.010 " (6.8.1953)

SEVİYE ÖLÇEĞİ : Eşel ve Limnigraf.

DÜŞÜNCELER : Akım durumu orta. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 12 akım ölçüldü yapılmıştır.

19. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
35	0.150	80	4.80
40	0.290	90	6.90
50	0.770	100	9.70
60	1.65	150	29.0
70	2.95	200	56.5

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.442	0.518	0.594	1.07	2.30	3.88	1.35	1.41	1.24	0.594	0.370	0.290
2	0.442	0.518	0.594	1.24	2.69	4.25	1.35	1.49	0.990	0.594	0.330	0.330
3	0.442	0.594	0.594	1.32	2.69	6.48	1.13	1.49	0.830	0.594	0.330	0.290
4	0.442	0.594	0.594	1.32	2.69	6.05	1.13	1.49	0.750	0.910	0.290	0.290
5	0.442	0.594	0.594	1.32	2.69	4.25	1.03	1.49	0.670	0.750	0.290	0.290
6	0.442	0.594	0.518	1.32	2.69	3.51	1.15	1.59	0.670	0.670	0.262	0.290
7	0.442	0.594	0.594	1.24	2.69	4.80	1.18	1.87	0.670	0.670	0.262	0.290
8	0.442	0.594	0.594	1.24	2.69	4.80	1.18	1.87	0.670	0.670	0.262	0.290
9	0.442	0.594	0.594	1.68	4.80	4.80	1.18	1.87	0.594	0.594	0.262	0.290
10	0.366	0.594	0.594	1.68	4.80	2.95	4.02	1.78	0.594	0.594	0.262	0.290
11	0.366	0.594	0.594	1.68	3.88	2.95	3.48	1.78	0.518	0.594	0.262	0.290
12	0.442	0.594	0.594	1.68	3.51	2.82	3.02	1.15	0.518	0.594	0.262	0.290
13	0.442	0.594	0.594	1.68	2.69	2.69	2.69	0.990	0.594	0.594	0.262	0.290
14	0.366	0.594	0.594	2.69	2.69	2.69	2.69	1.07	0.594	0.990	0.262	0.330
15	0.442	0.594	0.594	20.3	2.56	2.43	2.47	0.990	0.594	0.910	0.262	0.330
16	0.442	0.594	0.594	8.58	2.43	2.43	2.47	0.990	0.594	0.910	0.262	0.330
17	0.442	0.594	0.594	7.46	2.43	2.43	2.47	1.07	0.518	0.910	0.262	0.330
18	1.41	0.594	0.594	2.04	2.43	2.43	2.47	1.59	0.518	2.22	0.234	0.330
19	1.49	0.594	0.594	2.04	2.43	2.43	2.47	1.59	0.518	2.22	0.234	0.330
20	1.49	0.594	0.594	2.04	2.43	2.43	2.47	1.59	0.518	2.22	0.234	0.330
21	1.41	0.594	0.594	12.2	2.04	2.17	2.10	1.15	0.594	0.370	0.234	0.370
22	1.32	0.594	0.594	9.84	2.04	2.04	2.10	0.910	0.594	0.370	0.234	0.370
23	0.594	0.594	0.594	5.84	2.04	2.04	2.10	0.910	0.594	0.370	0.234	0.370
24	0.594	0.594	0.594	4.62	2.04	2.04	2.10	0.910	0.594	0.370	0.234	0.370
25	0.518	0.594	0.594	3.88	2.30	1.65	1.87	0.750	0.594	0.290	0.262	0.410
26	0.518	0.594	0.750	3.14	2.56	1.65	1.87	0.830	0.670	0.290	0.262	0.410
27	0.518	0.594	1.13	2.56	2.56	1.55	1.78	0.830	0.670	0.290	0.262	0.410
28	0.518	0.594	1.23	2.56	2.56	1.55	1.78	0.830	0.670	0.290	0.262	0.410
29	0.518	0.594	1.41	2.56	2.56	1.55	1.78	0.830	0.670	0.290	0.262	0.410
30	0.518	0.594	1.24	2.04	2.04	1.45	1.59	0.750	0.594	0.370	0.262	0.410
31	0.518	---	1.15	2.17	---	1.45	---	1.41	---	0.490	0.290	---
TOPLAM	20.172	17.592	22.368	136.20	85.11	84.45	70.67	38.320	19.482	22.178	8.590	10.060
ORTALAMA	0.651	0.586	0.722	4.394	3.040	2.724	2.356	1.236	0.649	0.719	0.277	0.335
LT/SN/KM ²	0.722	0.650	0.801	4.87	3.37	3.02	2.61	1.37	0.720	0.793	0.307	0.372
AKIM MM.	1.93	1.69	2.14	13.1	8.16	8.09	6.77	3.67	1.87	2.13	0.823	0.764
10 M AKIM	1.74	1.52	1.93	11.8	7.35	7.30	6.11	3.31	1.68	1.92	0.742	0.669

SU YILI (1983) YILLIK TOPLAM AKIM. 46.24 MİLYON M³, 51.3 MM , 1.63 LT/SN/KM².

(•) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 19.5 m³/sec. Tarihi 23.1.1983
Yıl içinde 3.Pik Akım Değeri 7.46 " Tarihi 7.4.1983

5 - GEDİZ HAVZASI
510 - KUM ÇAYI - KILLİK

YERİ : (27° 40' 58" D - 38° 47' 36" K) Manisa - Akhisar karayolunun 30. Km.esindeki Killik boğazındadır.

YAĞIŞ ALANI : 3184.8 km²

YAKLAŞIK KOT : 55 m.

GÖZLEM SÜRESİ : 11. Mayıs.1951 - 30. Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 7.854 m³/sn. (23 yıllık) 1983 Su yılında 3.523 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 119. m³/sn. (16.1.1983)

1983 Su yılında en az akım : 0.184 " (16.8.1983)

Gözlem süresinde en çok akım : 1494. " (8.2.1952)

Gözlem süresinde en az akım : 0.006 " (9.8.1973)

SEVİYE ÖLÇEĞİ : Egel.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 11 akım ölçüştü yapılmıştır.

35. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
55	0.100	100	4.40
60	0.520	150	13.9
70	1.45	200	30.0
80	2.30	250	54.0
90	3.26	350	131.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
2	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
3	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
4	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
5	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
6	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
7	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
8	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
9	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
10	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
11	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
12	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
13	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
14	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
15	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
16	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
17	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
18	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
19	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
20	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
21	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
22	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
23	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
24	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
25	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
26	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
27	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
28	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
29	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
30	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
31	2.50	2.60	2.50	3.03	3.45	5.62	3.39	3.37	2.25	1.71	0.692	0.352
TOPLAM	93.25	76.30	100.09	229.85	252.98	145.40	147.22	93.37	68.45	37.146	11.598	33.294
ORTALAMA	3.008	2.543	3.229	7.415	9.035	4.690	4.907	3.012	2.283	1.198	0.374	1.010
LT/SH/KM ²	0.944	0.798	1.01	2.33	2.84	1.47	1.54	0.946	0.717	0.376	0.117	0.317
AKIM MM.	2.53	2.07	2.72	6.24	6.86	3.94	3.99	2.53	1.86	1.01	0.314	0.922
10 M AKIM	8.06	6.59	8.65	19.9	21.9	12.6	12.7	8.07	5.92	3.21	1.00	2.62

SU YILI (1983) YILLIK TOPLAM AKIM. 111.1 MİLYON M³, 34.9 MM, 1.11 LT/SH/KM².

I = I AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLEPE GÜSTERİR. Yıl içinde 2.Pik Akım Değeri 60.0 m³/sec. Tarihi 5.2.1983
Yıl içinde 3.Pik Akım Değeri 27.4 " Tarihi 7.4.1983

5 - GEDİZ HAVZASI
514 - SELENDİ ÇAYI - DEREKÖY

YERİ : (28° 42' 01" D - 38° 41' 57" K) Manisa'nın Selendi ilçesine 15 Km. mesafededir.

YAĞIŞ ALANI : 689.6 Km²

YAKLAŞIK KOT : 345 m.

GÖZLEM SÜRESİ : 12.Nisan.1960 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 3.239 m³/sn. (20 yıllık) 1983 Su yılında 1.336 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 78.0 m³/sn. (4. 7.1983)

1983 Su yılında en az akım : 0.024 " (29. 7.1983)

Gözlem süresinde en çok akım : 860. " (15.12.1981)

Gözlem süresinde en az akım : Kuru (20. 8.1970)

SEVİYE ÖLÇEĞİ : Eşel.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 12 akım ölçüldü yapılmıştır. 15.12.1981 tarihinde, gözlem süresinde verilen en çok akım 860. m³/sn. olarak düzeltilmiştir.

26. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
110	Kuru	160	6.10
120	0.005	180	19.5
130	0.400	200	59.0
140	1.25	250	220.
150	2.75	300	410.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.183	0.362	0.324	0.970	1.65	4.00	0.900	0.970	0.788	0.102	1.50	0.162
2	0.156	0.362	0.324	1.04	2.29	4.20	0.900	0.970	0.788	0.129	1.77	0.152
3	0.156	0.362	0.324	0.676	2.02	9.80	0.900	0.844	0.788	0.732	0.658	0.181
4	0.210	0.362	0.324	0.620	3.20	10.4	0.844	0.788	1.88	2.56	0.822	0.100
5	0.324	0.362	0.286	0.676	3.68	5.60	0.788	0.788	7.20	1.75	0.548	0.103
6	0.248	0.444	0.286	0.576	3.05	3.37	1.55	0.732	2.29	0.770	0.474	0.100
7	0.248	0.400	0.286	0.532	2.29	3.37	18.0	0.676	2.74	0.622	0.340	0.381
8	0.210	0.362	0.324	0.488	2.29	3.05	8.00	0.676	17.0	0.548	0.280	0.303
9	0.183	0.362	0.324	0.488	3.37	5.60	2.80	0.676	4.84	0.474	0.280	0.662
10	0.183	0.400	0.324	0.488	3.68	5.60	4.00	0.676	1.35	4.34	0.280	0.662
11	0.156	0.400	0.324	0.444	2.29	5.20	2.74	0.676	1.18	4.34	0.280	0.362
12	0.210	0.400	0.324	0.444	2.29	3.68	2.15	0.676	1.11	1.68	0.340	0.362
13	1.18	0.400	0.324	0.444	2.02	3.37	2.02	0.676	0.970	1.75	0.340	0.362
14	1.35	0.400	0.324	0.444	2.15	3.37	1.75	0.620	0.844	1.25	0.400	0.362
15	0.788	0.400	0.324	0.400	2.02	2.29	1.75	0.576	1.04	1.06	0.280	0.362
16	0.576	0.400	0.324	6.40	1.75	2.29	1.75	0.576	0.970	0.762	0.220	0.362
17	1.11	0.400	0.324	6.80	2.29	2.15	1.65	0.576	0.900	0.962	0.220	0.362
18	0.676	0.400	0.324	2.02	2.29	2.02	1.35	0.620	0.620	1.50	0.220	0.362
19	0.676	0.362	0.324	2.02	1.65	1.88	1.35	0.788	0.488	1.75	0.280	0.362
20	0.620	0.362	0.400	1.75	1.35	1.75	1.35	0.788	0.444	0.965	0.280	0.362
21	0.620	0.362	0.488	12.2	1.35	1.75	1.35	0.844	0.362	0.622	0.160	0.362
22	0.488	0.362	0.400	8.00	1.35	1.65	1.35	0.286	0.474	0.186	0.362	0.362
23	0.444	0.362	0.400	6.80	2.15	1.35	1.25	2.15	0.248	0.340	0.160	0.362
24	0.444	0.362	0.400	4.00	1.65	1.45	1.25	1.18	0.286	0.160	0.160	0.362
25	0.444	0.362	0.488	2.42	1.45	1.45	1.25	0.900	0.362	0.160	0.081	0.362
26	0.444	0.362	0.970	1.65	1.35	1.25	1.18	0.788	0.286	0.622	0.062	0.362
27	0.400	0.362	1.04	1.45	1.35	1.18	1.18	0.732	0.210	0.043	0.062	0.362
28	0.400	0.324	1.04	1.45	1.75	1.11	1.11	0.620	0.129	0.043	0.062	0.362
29	0.400	0.324	0.788	1.35	---	1.11	1.04	0.576	0.075	0.024	0.062	0.362
30	0.400	0.324	1.35	1.25	---	1.11	1.04	0.576	0.102	0.062	0.062	0.362
31	0.362	---	1.45	1.25	---	0.970	---	0.676	---	1.37	0.062	---
TOPLAM	14.489	11.208	15.256	69.540	62.15	101.840	71.142	26.460	50.536	53.367	0.623	1.879
ORTALAMA	0.467	0.374	0.492	2.243	2.220	3.285	2.371	0.854	1.685	1.727	0.310	0.593
LT/SH/KM ²	0.677	0.542	0.713	3.25	3.22	4.76	3.44	1.24	2.44	2.50	0.450	0.091
AKIM MM ³	1.82	1.40	1.91	8.71	7.79	12.8	8.91	3.32	6.33	6.69	1.21	0.235
10 M AKIM	1.25	0.969	1.32	6.01	5.37	8.80	6.15	2.29	4.37	4.61	0.931	0.152

SU YILI : 1983 YILLIK TOPLAM AKIM : 42.12 MİLYON M³ , 61.1 MM , 1.94 LT/SH/KM².

1 * 1 AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 44.4 m³/sec. Tarihi 8.6.1983
Yıl içinde 3.Pik Akım Değeri 43.1 " Tarihi 21.1.1983

5 - GÖZLEM HAVZASI
515 - DELİNTİS DERESİ - TOPUZDAMLARI

YERİ : (25° 33' 15" D - 38° 43' 27" E) Manisa'nın Selendi ilçesine 20 Km. uzaklıktadır.

YAGIŞ ALANI : 739.6 Km²

YAKLAŞIK KOT : 375 m.

GÖZLEM SÜRESİ : 14.Nisan.1960 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 4.158 m³/sn. (18 yıllık) 1983 Su yılında 1.505 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 112. m³/sn. (31. 7.1983)

1983 Su yılında en az akım : 0.003 " (30. 6.1983)

Gözlem süresinde en çok akım : 1025. " (15.12.1981)

Gözlem süresinde en az akım : 0.003 " (11. 8.1980)

SEVİYE ÖLÇEĞİ : Eşel.

DÜŞÜNCELER : Akım Durumu iyi. Yıl içinde 12 akım ölçüldü yapılmıştır. 15.12.1981 tarihinde, gözlem süresinde verilen en çok akım 1025. m³/sn. olarak düzeltilmiştir.

17. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
15	0.000	100	16.5
20	0.030	150	40.0
30	0.310	200	72.0
40	1.30	250	112.
50	2.75	300	160.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.228	0.392	0.478	1.72	2.15	6.75	1.58	1.18	0.638	0.003	5.50	3.060
2	0.228	0.310	0.478	1.44	2.00	10.2	1.72	1.18	0.638	0.003	5.50	3.060
3	0.228	0.310	0.478	1.44	2.00	11.1	1.86	1.07	0.836	0.011	0.720	1.18
4	0.269	0.310	0.478	1.30	2.75	10.5	1.72	0.952	3.39	2.60	0.638	0.478
5	0.392	0.392	0.556	1.30	4.12	9.32	1.72	0.952	3.39	2.60	0.556	3.269
6	0.310	0.392	0.556	1.58	3.50	6.75	5.25	0.952	1.72	*1.07	0.392	3.187
7	0.269	0.392	0.478	2.45	2.91	4.12	13.4	0.836	1.07	0.720	0.310	3.146
8	0.269	0.310	0.478	2.00	2.75	3.07	7.03	0.836	1.07	0.438	0.310	1.105
9	0.269	0.392	0.478	2.00	2.75	3.07	9.00	0.836	0.310	0.836	0.269	0.390
10	0.228	0.392	0.478	1.58	2.75	3.39	4.31	0.836	0.478	2.91	0.228	0.075
11	0.228	*0.392	0.556	1.30	2.75	3.74	3.55	0.720	0.269	3.55	0.187	0.075
12	0.638	0.310	0.638	1.18	2.60	3.93	3.23	0.720	0.146	1.72	0.187	3.075
13	1.30	0.310	0.638	0.952	2.45	3.55	2.91	0.638	0.103	1.07	0.228	0.075
14	0.720	0.392	0.720	0.952	2.30	2.75	2.60	0.338	0.269	0.836	0.269	*0.060
15				1.07	2.30		2.30	0.478	*1.18	0.638	0.228	0.060
16	0.556	0.392	0.836	3.00	*2.15	2.75	2.30	0.392	0.228	0.356	0.187	0.060
17	3.50	0.392	0.836	2.45	2.60	2.30	2.30	0.310	0.090	0.720	0.187	0.060
18	4.12	0.478	0.836	2.00	2.60	2.60	2.15	*0.392	0.060	2.60	0.146	3.060
19	*0.952	0.478	0.836	*2.00	2.45	2.45	2.15	0.556	0.090	0.356	0.075	0.075
20	*0.478	0.478	0.952	2.00	2.45	2.30	2.00	1.86	0.045	0.228	0.090	0.090
21	0.478	0.478	*1.18	11.8	2.15	2.30	*2.00	1.72	0.030	0.146	0.090	4.105
22	0.392	0.478	0.952	9.61	2.00	2.15	1.86	1.86	0.030	0.103	0.090	3.090
23	0.392	0.478	0.720	7.58	2.30	1.86	1.72	2.14	0.030	0.103	0.090	1.125
24	0.310	0.478	0.638	4.12	2.30	1.86	1.58	1.58	0.015	0.075	*0.075	0.125
25	0.310	0.392	1.07	3.39	2.30	1.86	1.58	1.58	0.015	0.075	*0.075	0.125
26	0.260	0.392	2.30	2.75	2.15	1.86	1.58	1.18	0.015	0.060	0.075	0.146
27	0.269	0.392	2.30	2.30	2.15	1.72	1.44	0.952	0.011	0.060	0.075	0.146
28	0.269	0.478	1.86	2.00	2.60	1.72	1.44	0.720	0.011	0.060	0.075	0.146
29	0.269	0.556	1.30	1.86	---	1.72	1.30	0.556	0.007	0.060	0.075	0.146
30	0.310	0.478	1.44	1.72	---	1.72	1.18	0.638	0.003	0.060	0.075	0.146
31	0.392	---	2.00	1.86	---	1.58	---	1.07	---	1.39	0.060	---
TOPLAM	22.273	12.206	28.264	88.244	75.73	118.36	84.73	37.568	16.047	48.976	12.070	4.707
ORTALAMA	0.718	0.407	0.912	2.847	2.705	3.818	2.824	1.212	0.535	1.580	0.389	0.157
LT/SH/KM	0.971	0.550	1.23	3.85	3.66	5.16	3.82	1.64	0.723	2.14	0.526	0.212
AKIM MM.	2.60	1.43	3.30	10.3	8.85	13.8	9.90	4.39	1.87	5.72	1.41	0.550
10 M AKIM	1.92	1.05	2.44	7.62	6.54	10.2	7.32	3.25	1.39	4.23	1.04	0.407

SU YILI (1983) YILLIK TOPLAM AKIM. 47.45 MİLYON M³ 64.2 MM. 2.03 LT/SH/KM²

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 95.0 m³/sec. Tarihi 4.7.1983
Yıl içinde 3.Pik Akım Değeri 25.0 " Tarihi 21.1.1983

5 - GEDİZ HAVZARI
518 - GEDİZ NEHRİ - MANİSA

YERİ : (27° 26' 35" D - 38° 38' 41" E) Manisa - Akhisar çıkışındaki yolun 2. Km.indedir.

YAĞIŞ ALANI : 15616.4 Km²

YAKLAŞIK KOT : 23 m.

GÖZLEM SÜRESİ : 9.Şubat.1962 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 59.762 m³/sn. (21 yıllık) 1983 Su yılında 33.651 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 278. m³/sn. (17.1.1983)
1983 Su yılında en az akım : 8.20 " (30.9.1983)
Gözlem süresinde en çok akım : 812. " (31.1.1963)
Gözlem süresinde en az akım : 3.80 " (25.6.1977)

SEVİYE ÖLÇEĞİ : Eşel ve Limnigraf.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 12 akım ölçüştü yapılmıştır. Sediment numunesi alınmaktadır.

21. Anahtar eğrisi (Seviyeler Cm. Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
70	7.00	200	74.0
80	11.2	250	109.1
90	15.6	300	146.
100	20.2	400	247.
150	43.8	500	400.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NISAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	27.6	36.8	50.6	63.3	44.0	40.0	30.0	21.0	12.6	13.4	23.0	12.6
2	30.0	38.1	47.5	40.0	120.5	46.0	30.0	21.0	12.6	12.6	23.5	14.0
3	30.0	38.9	48.0	38.0	78.5	46.5	32.3	20.6	11.8	12.6	20.6	14.0
4	31.4	43.5	48.5	48.0	99.0	53.3	32.3	20.6	11.8	12.6	20.6	14.0
5	34.4	41.5	50.6	58.4	118.4	66.2	29.1	20.6	11.8	11.8	17.0	19.0
6	46.9	42.0	44.5	59.5	19.2	51.8	33.2	20.2	13.4	13.4	16.3	16.3
7	41.8	45.0	48.0	48.5	63.5	46.5	103.4	19.4	16.2	13.4	15.4	18.6
8	40.3	39.0	47.3	43.0	58.4	44.5	106.5	18.6	17.8	12.2	16.6	23.5
9	36.9	38.1	44.5	43.0	54.5	44.5	65.5	18.2	15.0	11.0	17.4	28.0
10	35.4	44.5	40.5	41.0	49.6	43.0	51.8	16.3	14.6	9.40	18.2	28.5
11	43.3	40.5	38.6	43.0	45.5	44.5	45.5	18.2	14.2	10.6	18.2	28.0
12	41.8	41.5	41.5	47.5	42.5	44.5	41.0	17.0	11.8	20.6	18.6	24.0
13	46.9	41.5	39.0	46.5	45.0	44.5	38.1	16.3	16.3	17.4	19.6	23.0
14	31.2	38.6	40.0	39.0	44.5	43.0	35.9	18.0	16.0	13.4	19.6	19.6
15	62.1	29.6	39.5	38.1	41.0	42.5	38.6	14.2	13.0	13.4	20.6	19.7
16	57.3	30.9	39.0	47.0	39.0	40.5	32.7	13.4	15.0	12.6	23.0	23.4
17	50.1	30.0	38.1	173.4	38.1	39.5	31.4	13.4	14.2	10.6	23.0	24.0
18	49.6	23.5	35.9	92.0	38.1	37.1	30.9	17.0	12.6	9.60	19.6	26.0
19	56.2	40.0	35.9	72.3	38.1	37.2	29.6	19.6	13.6	9.80	17.4	17.4
20	58.4	47.5	38.6	51.2	35.9	35.4	27.3	23.0	11.8	11.0	17.4	16.3
21	59.4	49.6	63.3	68.1	35.0	35.4	26.4	22.6	13.4	9.80	17.8	16.3
22	57.3	41.5	56.7	114.4	32.5	32.5	26.0	20.6	13.8	9.00	15.8	20.6
23	45.5	35.0	42.7	90.6	56.7	33.3	25.3	17.8	13.4	10.2	16.6	19.6
24	43.0	40.0	40.0	66.2	73.3	33.3	25.3	17.8	13.4	10.2	16.3	19.6
25	41.5	50.6	41.5	57.8	49.0	32.7	29.1	18.0	14.2	10.2	17.0	19.7
26	35.0	49.0	55.1	50.1	43.0	32.7	24.3	15.0	13.8	11.0	17.0	18.8
27	39.0	48.0	74.0	44.0	40.5	35.0	21.8	13.8	13.8	11.0	17.0	13.0
28	50.1	42.5	63.0	41.5	38.6	38.6	21.4	13.0	13.4	13.0	14.2	10.8
29	32.9	38.6	63.0	41.5	38.6	33.6	21.4	11.8	13.0	17.4	14.2	10.8
30	40.0	36.3	60.6	38.6	---	---	---	---	---	---	---	---
31	35.4	---	78.5	36.8	---	31.4	---	11.8	---	19.4	12.6	---
TOPLAM	1389.2	1232.7	1493.4	1781.6	1543.4	1279.3	1102.1	536.5	398.80	399.50	552.5	573.7
ORTALAMA	44.81	41.09	48.17	57.47	55.12	41.27	36.74	17.31	13.29	12.89	17.82	19.12
LT/SN/KM ²	2.87	2.63	3.08	3.68	3.53	2.64	2.35	1.11	0.851	0.825	1.14	1.22
AKIM MM.	7.69	6.82	8.26	9.86	8.54	7.08	6.10	2.97	2.21	2.21	3.06	3.17
10 M AKIM	120.	107.	129.	154.	133.	111.	95.2	46.4	34.5	34.5	47.7	49.6

SU YILI (1983) YILLIK TOPLAM AKIM. 1061. MİLYON M³, 68.0 MM, 2.15 LT/SN/KM².

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 166. m³/sec. Tarihi 5.2.1983
Yıl içinde 3.Pik Akım Değeri 162. " Tarihi 7.4.1983

5 - GEDİZ HAVZASI
522 - DEMİRCİ ÇAYI - BORLU KÖP.

YERİ : (38° 58' 25" D - 38° 44' 29" K) Salihli - Demirci yolu üzerindeki Borlu Buoğuna
1.5 Km. uzaklıktaki beton köprühün 150 m. mansabındadır.

YAĞIŞ ALANI : 818.8 Km²

YAKLAŞIK KOT : 245 m.

GÖZLEM SÜRESİ : 1.Haziran.1970 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 4.061 m³/sn. (13 yıllık) 1983 Su yılında 1.486 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 111. m³/sn. (18.7.1983)
1983 Su yılında en az akım : Kuru (31.8.1983)
Gözlem süresinde en çok akım : 890. m³/sn. (15.12.1981)
Gözlem süresinde en az akım : Kuru (19. 7.1972)

SEVİYE ÖLÇEĞİ : Eşel ve Limnigraf.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 12 akım ölçüsü yapılmıştır.

13. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
450	Kuru	500	7.90
460	0.090	510	11.0
470	0.725	550	26.2
480	2.55	600	69.6
490	5.00	650	142.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDİ METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.050	0.400	0.475	1.47	1.87	6.45	1.65	1.28	1.65	0.040	7.63	KURU
2	0.050	0.400	0.400	1.03	4.25	8.21	1.65	1.14	1.14	0.085	0.646	0.005
3	0.050	0.400	0.400	0.910	4.25	8.83	1.28	1.14	0.884	1.14	0.409	0.010
4	0.075	0.400	0.475	1.15	5.38	4.25	1.28	1.00	0.725	2.32	0.330	0.010
5	0.075	0.400	0.475	1.15	5.38	4.25	1.28	1.00	0.646	2.32	0.281	0.010
6	0.075	0.325	0.550	1.03	4.25	4.00	3.03	1.00	4.00	0.646	0.232	0.023
7	0.075	0.325	0.550	0.910	3.51	3.51	3.51	0.884	4.00	0.488	0.232	0.023
8	0.075	0.325	0.550	0.790	3.51	3.51	3.51	0.884	2.10	0.330	0.183	0.040
9	0.075	0.400	0.550	0.790	3.51	3.75	4.00	0.884	2.42	0.232	0.134	0.040
10	0.100	0.400	0.670	0.910	3.51	3.75	5.00	0.884	0.884	0.232	0.083	0.040
11	0.100	0.400	0.670	0.910	3.27	4.00	4.25	0.884	0.725	3.03	0.050	0.023
12	0.100	0.325	0.670	0.910	3.27	5.38	3.51	0.725	0.646	1.00	0.023	0.040
13	0.100	0.325	0.670	0.790	3.27	4.75	3.51	0.725	0.488	0.409	0.023	0.040
14	0.100	0.325	0.670	0.790	3.27	4.75	3.51	0.646	0.409	0.281	0.023	0.023
15	0.400	0.400	0.670	0.910	2.55	3.51	2.79	0.646	0.646	0.183	0.023	0.010
16	0.400	0.475	0.670	11.6	1.87	3.27	2.32	0.646	0.646	0.134	0.023	0.010
17	1.31	0.550	0.670	12.5	2.79	2.79	2.32	0.646	0.567	0.232	0.023	0.010
18	1.03	0.550	0.790	3.51	2.79	3.03	2.32	0.646	0.488	0.646	0.023	0.010
19	0.670	0.550	0.790	2.49	1.65	3.03	1.87	0.646	0.488	0.330	0.023	0.010
20	0.670	0.475	1.15	1.95	1.65	2.79	1.65	1.14	0.409	0.330	0.023	0.010
21	0.550	0.475	1.79	11.0	1.42	3.03	1.87	4.50	0.330	0.409	0.023	0.010
22	0.475	0.475	1.03	16.8	1.65	2.55	1.87	4.00	0.291	0.330	0.023	0.010
23	0.475	0.475	0.910	6.16	3.27	2.55	1.87	2.79	0.232	0.281	0.023	0.010
24	0.400	0.475	0.910	2.79	2.32	2.32	1.65	1.42	0.183	0.281	0.023	0.010
25	0.400	0.400	1.03	2.79	2.32	1.87	1.65	1.00	0.183	0.281	0.023	0.010
26	0.400	0.400	2.49	2.10	2.10	2.10	1.42	0.884	0.183	0.232	0.023	0.023
27	0.400	0.400	2.67	1.87	2.55	2.10	1.42	0.646	0.134	0.232	0.023	0.023
28	0.400	0.400	1.95	1.65	3.27	1.87	1.42	0.567	0.083	0.183	0.023	0.023
29	0.400	0.475	1.31	1.42	1.42	1.87	1.28	0.567	0.050	0.183	0.023	0.023
30	0.400	0.475	1.31	1.28	1.28	1.65	1.28	1.14	0.040	0.183	0.010	0.023
31	0.400	---	1.79	1.14	---	1.87	---	4.25	---	0.409	KURU	---
TOPLAM	11.075	12.600	30.425	96.350	87.76	112.60	89.78	39.090	22.947	29.042	10.036	0.569
ORTALAMA	0.357	0.420	0.981	3.108	3.134	3.632	2.993	1.261	0.765	0.937	0.324	0.019
LT/SN/KM ²	0.436	0.513	1.20	3.80	3.83	4.44	3.66	1.54	0.934	1.14	0.396	0.023
AKIM/MM.	1.17	1.33	3.21	10.2	9.26	11.9	9.47	4.12	2.42	3.06	1.06	0.060
10 M AKIM	0.957	1.09	2.63	8.32	7.58	9.73	7.76	3.38	1.98	2.51	0.867	0.049

SU YILI (1983) YILLIK TOPLAM AKIM. 46.85 MİLYON M³, 57.2 MM, 1.81 LT/SN/KM².

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 74.7 m³/sec. Tarihi 22.1.1983
Yıl içinde 3.Pik Akım Değeri 43.2 " Tarihi 1.8.1983

5 - GEDİZ HAVZASI
523 - GEDİZ HEVİ - ACISU

YERİ : (28° 43' 18" D - 38° 38' 26" K) Kula- Selendi karayolu Üzerindeki Gediz köprü-
sünün 2 Km. manzabında, Acisu civarındadır.

YAĞIŞ ALANI : 3272.4 Km²

YAKLAŞIK KOT : 365 m.

GÖZLEM SÜRESİ : 14.Haziran.1968 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 12.385 m³/sn. (14 yıllık) 1983 Su yılında 7.503 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 225. m³/sn. (8.7.1983)
1983 Su yılında en az akım : 0.466 " (26.8.1983)
Gözlem süresinde en çok akım : 773. " (28.1.1966)
Gözlem süresinde en az akım : 0.286 " (7.8.1972)

SEVİYE ÖLÇEĞİ : Eşel ve Limnigraf.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 13 akım ölçüldü yapılmıştır. Sediment numunesi alınmaktadır.

11. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
20	Kuru	100	29.0
30	0.730	150	83.0
40	1.92	200	165.
50	4.00	250	268.
60	7.20	300	390.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	2.30	3.82	4.08	7.26	7.60	17.2	11.0	7.26	8.12	2.09	3.75	0.730
2	2.10	3.56	4.34	6.92	11.5	33.9	11.0	8.28	8.12	2.59	2.59	0.730
3	2.10	3.30	4.60	6.58	15.2	10.6	12.7	4.86	4.86	2.42	0.554	
4	3.82	3.10	4.60	6.24	19.4	37.5	10.2	9.36	7.26	3.50	2.26	0.958
5	5.90	3.82	4.34	5.90	16.2	22.5	11.0	8.96	20.7	8.84	2.09	0.958
6	5.12	4.08	4.08	5.64	15.7	17.2	12.7	8.26	26.3	4.32	2.09	0.958
7	4.60	3.82	4.08	5.12	15.2	15.7	12.7	7.60	14.6	3.50	1.92	1.07
8	4.08	3.56	3.82	4.60	14.1	14.1	11.0	6.92	23.0	3.26	1.80	1.07
9	3.82	3.82	3.82	4.34	11.9	12.3	12.3	6.58	4.25	3.01	1.80	1.07
10	3.56	4.08	3.82	4.08	11.0	12.3	20.7	6.58	4.60	4.60	1.67	1.07
11	3.30	4.08	3.82	4.34	10.6	15.2	18.8	6.24	8.43	14.6	1.55	1.07
12	5.64	3.82	3.82	4.60	10.2	18.8	16.2	6.56	8.02	14.1	1.67	1.19
13	9.73	3.56	4.08	4.60	11.0	20.7	13.6	6.24	6.88	15.1	2.75	1.37
14	18.3	3.82	4.08	4.60	11.9	14.6	13.6	5.90	8.84	8.84	2.59	0.958
15	12.7	4.08	4.08	4.86	11.0	12.7	15.2	5.38	4.25	6.24	2.26	0.958
16	11.5	4.34	4.08	11.9	9.73	11.5	15.2	4.86	4.96	4.96	0.844	0.642
17	28.4	4.60	3.82	10.2	9.73	14.6	14.6	4.08	4.08	3.75	0.730	0.730
18	20.7	4.60	3.82	10.2	15.7	15.7	13.6	4.08	4.08	4.08	0.844	0.958
19	9.30	4.34	3.82	6.58	14.6	14.6	12.3	7.94	3.50	4.64	0.730	0.958
20	7.94	5.12	4.08	7.26	11.5	14.6	10.2	8.62	3.50	3.75	0.730	0.958
21	7.60	7.60	4.08	14.6	10.2	14.1	9.73	7.26	3.26	2.76	0.642	0.958
22	7.26	5.64	4.34	33.9	10.2	13.6	9.30	9.73	2.76	2.26	0.642	0.958
23	6.92	4.64	4.34	21.9	15.7	12.7	8.96	13.6	2.76	2.26	0.642	0.958
24	6.58	4.08	4.34	15.2	16.7	12.3	8.28	11.9	2.59	2.42	0.642	0.958
25	6.24	3.82	4.34	12.3	14.6	11.9	7.60	11.9	2.59	2.42	0.642	1.19
26	5.90	3.82	4.86	10.2	11.9	11.5	7.26	11.9	2.42	2.76	0.554	1.19
27	5.12	3.82	5.12	8.28	10.6	11.0	9.30	9.73	2.26	1.80	0.466	1.30
28	4.60	3.82	6.24	6.92	10.6	11.9	8.96	9.30	2.26	1.55	0.554	1.19
29	4.34	3.82	6.24	5.90	---	11.9	8.28	7.26	2.09	1.92	0.554	1.30
30	4.08	4.08	6.58	5.64	---	11.5	7.60	5.64	2.26	0.72	0.642	1.42
31	3.82	---	7.94	5.12	---	11.0	---	4.60	---	5.28	0.730	---
TOPLAM	227.37	124.16	139.76	276.88	354.26	492.4	431.57	248.62	222.56	147.61	43.518	29.854
ORTALAMA	7.335	4.139	4.508	8.932	12.65	15.88	14.39	8.020	7.419	4.762	1.404	0.995
LT/SN/KM ²	2.24	1.26	1.38	2.73	3.87	4.85	4.40	2.45	2.27	1.46	0.429	0.304
AKIM MM.	6.00	3.28	3.69	7.31	9.35	13.0	11.4	6.56	5.88	3.90	1.15	0.788
10 M AKIM	19.6	10.7	12.1	23.9	30.6	42.5	37.3	21.5	19.2	12.8	3.76	2.58

SU YILI (1983) YILLIK TOPLAM AKIM. 236.6 MİLYON M³, 72.3 MM. 2.29 LT/SN/KM².

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 90.5 m³/sec. Tarihi 7.4.1983
Yıl içinde 3.Pik Akım Değeri 80.2 " Tarihi 22.1.1983

5 - GEDİZ HAVZASI
524 - MURAT ÇAYI - SAZKÖY

YERİ : (29° 30' 42" N - 38° 57' 26" E) "Çak'a bağlı Gediz - Muratdağ yolunun yaklaşık 14. Km.esindeki köprüdür.

YAĞIŞ ALANI : 176.0 Km²

YAKLAŞIK KOT : 790 m.

GÖZLEM SÜRESİ : 1.Ekim.1972 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 1.775 m³/sn. (11 yıllık) 1981 Su yılında 1.371 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 6.90 m³/sn. (6. 4.1983)
1983 Su yılında en az akım : 0.425 " (30. 8.1983)
Gözlem süresinde en çok akım : 100. " (15.12.1981)
Gözlem süresinde en az akım : 0.285 " (28. 8.1973)

SEVİYE ÖLÇEĞİ : Fşel.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 12 akım ölçüldü yapılmıştır.

16. Anahtar eğrisi (Seviyeler Cm. Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
75	0.035	120	6.15
80	0.140	130	8.75
90	0.710	140	116.
100	1.95	150	14.6
110	3.75	200	32.0

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLUPAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.664	0.880	0.720	0.960	1.12	1.30	3.95	3.19	1.82	1.08	0.958	0.482
2	0.664	0.880	0.720	0.880	1.12	1.12	3.95	3.19	1.82	1.45	0.710	0.596
3	0.664	0.880	0.720	0.800	1.04	1.12	4.14	3.38	1.82	1.45	0.596	0.539
4	0.720	0.880	0.664	0.800	1.04	1.12	3.38	3.38	1.82	1.21	0.596	0.539
5	0.720	0.880	0.664	0.720	1.04	1.30	2.14	3.38	2.60	0.958	0.653	0.596
6	0.664	0.880	0.664	0.720	1.12	1.30	4.71	3.00	3.03	0.834	0.653	0.596
7	0.664	0.960	0.664	0.720	0.960	1.12	4.52	2.60	2.49	1.08	0.653	0.539
8	0.664	0.960	0.664	0.720	0.960	1.12	4.14	2.20	1.45	1.45	0.653	0.539
9	0.664	0.960	0.664	0.720	0.960	1.12	3.95	2.00	1.70	1.21	0.596	0.539
10	0.608	0.960	0.664	0.720	0.960	1.47	3.57	2.00	1.83	1.21	0.596	0.539
11	0.608	1.04	0.720	0.664	1.04	1.65	3.38	2.20	1.70	1.21	0.596	0.482
12	0.664	1.04	0.720	0.720	1.65	1.65	3.37	2.20	1.45	0.958	0.596	0.482
13	1.04	1.04	0.720	0.720	1.82	1.82	3.57	2.00	1.45	0.958	0.539	0.482
14	1.12	1.04	0.720	0.720	1.82	1.82	3.76	2.00	1.45	1.08	0.596	0.482
15	1.04	1.04	0.720	0.880	1.47	2.00	3.38	2.00	1.45	0.958	0.596	0.482
16	1.30	1.04	0.720	1.30	1.30	1.82	3.38	2.00	1.45	0.958	0.539	0.482
17	2.40	1.04	0.664	0.960	1.65	1.82	3.19	2.00	1.33	0.834	0.596	0.482
18	1.04	1.04	0.720	0.880	1.47	1.82	3.00	2.00	1.33	0.834	0.539	0.539
19	1.04	1.12	0.720	0.800	1.47	2.00	3.19	2.00	1.45	0.834	0.539	0.539
20	1.04	1.04	0.800	0.960	1.30	2.00	2.80	1.82	1.45	0.834	0.539	0.539
21	1.04	0.960	0.880	1.82	1.30	2.00	2.60	1.82	1.45	0.958	0.539	0.539
22	1.04	0.960	0.800	1.47	1.30	2.00	2.60	1.82	1.45	0.958	0.539	0.596
23	0.960	0.880	0.800	1.12	1.65	2.60	2.60	1.82	1.45	0.958	0.539	0.482
24	0.960	0.880	0.800	1.04	1.65	2.60	2.40	2.00	1.98	0.834	0.482	0.596
25	0.960	0.800	0.960	1.04	1.47	2.80	2.60	2.00	1.45	0.834	0.482	0.596
26	0.960	0.800	1.04	0.960	1.47	3.19	3.00	2.00	1.45	0.958	0.482	0.596
27	0.880	0.800	1.04	0.960	1.30	3.38	3.00	1.82	1.33	0.958	0.482	0.539
28	0.880	0.720	0.960	0.960	1.30	3.76	3.19	1.82	1.33	0.834	0.482	0.539
29	0.880	0.720	0.960	0.880	---	3.76	3.19	1.82	1.33	0.834	0.482	0.539
30	0.880	0.720	1.12	0.880	---	3.95	3.19	1.82	1.08	1.21	0.425	0.539
31	0.880	---	1.12	0.960	---	3.95	---	1.82	---	1.70	0.425	---
TOPLAM	28.308	27.840	24.512	28.454	36.060	64.28	102.61	69.48	52.33	32.556	17.698	16.170
ORTALAMA	0.913	0.928	0.791	0.918	1.288	2.074	3.420	2.241	1.744	1.050	0.571	0.539
LT/SN/KM ²	5.19	5.27	4.49	5.22	7.32	11.8	19.4	12.7	9.91	5.97	3.24	3.06
AKIM,MM.	13.9	13.7	12.0	14.0	17.7	31.6	50.4	34.1	25.7	16.0	8.69	7.94
10 M AKIM	2.45	2.41	2.12	2.46	3.12	5.55	8.87	6.00	4.52	2.81	1.53	1.40

SU YILI (1983) YILLIK TOPLAM AKIM. 43.23 MİLYON M³, 246. MM , 7.79 LT/SN/KM².

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Fik Akım Değeri 4.90 m³/sec. Tarihi 5.6.1983
Yıl içinde 3.Fik Akım Değeri 3.95 " Tarihi 30.3.1983

5 - GÖZLEM HAVZASI
525 - YIĞITLER DERESİ - YIĞITLER

YERİ : Turgutlu - Karpalpa karayolunun 12. Km. sında, Yiğitler Köyündeki köprünün 20 m. membairındadır.

YAĞIŞ ALANI : 64.0 Km²

YAKLAŞIK KOT : 165 m.

GÖZLEM SÜRESİ : 7.Kasım.1974 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 0.997 m³/sn. (8 yıllık) 1983 Su yılında 0.802 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 20.0 m³/sn. (16. 1.1983)

1983 Su yılında en az akım : 0.005 " (26. 7.1983)

Gözlem süresinde en çok akım : 153. " (15.12.1981)

Gözlem süresinde en az akım : 0.005 " (25. 9.1980)

SEVİYE ÖLÇEĞİ : Fgel.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 11 akım ölçüldü yapılmıştır.

9. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
60	0.015	110	17.5
70	0.500	120	22.5
80	3.55	130	27.5
90	7.70	140	32.5
100	12.6	150	37.5

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLARAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.144	0.144	0.322	1.03	4.31	3.22	1.33	0.411	0.144	0.031	0.233	0.047
2	0.144	0.144	0.322	0.776	4.31	3.55	1.33	0.322	0.055	0.023	0.144	0.047
3	0.233	0.144	0.411	0.776	3.55	4.31	1.33	0.322	0.144	0.031	0.233	0.039
4	0.322	0.144	0.411	0.776	3.55	3.55	1.33	0.322	0.055	0.031	0.233	0.039
5												
6	0.322	0.322	0.411	0.776	4.31	3.22	2.88	0.322	0.233	0.023	0.233	0.039
7	0.322	0.322	0.411	0.500	2.21	3.22	3.55	0.322	0.233	0.031	0.233	0.039
8	0.144	0.233	0.411	0.776	2.21	2.88	2.55	0.322	0.144	0.031	0.144	0.023
9	0.144	0.233	0.411	0.776	2.21	2.88	2.55	0.322	0.144	0.031	0.144	0.023
10	0.144	0.233	0.411	0.776	2.21	2.55	1.88	0.322	0.144	0.031	0.233	0.047
11	0.144	0.233	0.411	0.776	2.21	2.55	1.88	0.411	0.055	0.055	0.144	0.047
12	0.144	0.233	0.411	0.776	2.21	2.55	1.88	0.411	0.055	0.055	0.144	0.047
13	0.144	0.233	0.411	0.500	2.21	2.55	1.88	0.411	0.039	0.047	0.500	0.144
14	0.233	0.233	0.411	0.500	2.21	2.55	1.33	0.411	0.039	0.047	0.411	0.055
15	0.233	0.233	0.500	0.776	2.21	2.21	1.33	0.411	0.047	0.047	0.055	0.031
16	0.322	0.233	0.500	6.35	1.60	2.55	1.33	0.322	0.047	0.039	0.055	0.231
17	0.322	0.233	0.411	0.500	1.60	2.21	1.05	0.411	0.047	0.039	0.047	0.039
18	0.322	0.144	0.776	0.500	1.60	2.21	1.05	0.411	0.047	0.039	0.047	0.039
19	0.322	0.322	0.776	1.33	1.60	2.21	1.05	0.411	0.047	0.039	0.047	0.055
20	0.322	0.322	2.21	1.05	1.33	2.21	1.05	0.411	0.047	0.031	0.047	0.144
21	0.233	0.322	1.60	3.55	1.60	2.21	1.05	0.411	0.047	0.031	0.047	0.055
22	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
23	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
24	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
25	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
26	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
27	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
28	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
29	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
30	0.233	0.322	1.33	3.93	1.33	2.21	1.05	0.322	0.055	0.039	0.233	0.047
31	0.144	---	1.88	0.776	---	1.33	---	0.055	---	0.031	0.039	---
TOPLAM	6.956	6.990	32.549	35.558	75.65	77.00	39.561	9.270	2.171	0.959	4.352	1.694
ORTALAMA	0.224	0.233	1.050	1.147	2.702	2.484	1.319	0.299	0.072	0.031	0.140	0.056
LT/SN/KM ²	3.50	3.64	16.4	17.9	42.2	38.8	20.6	4.67	1.12	0.484	2.19	0.875
AKIM MM.	9.39	9.44	43.9	48.0	102.	104.	53.4	12.5	2.93	1.29	5.88	2.29
10 M AKIM	0.601	0.604	2.81	3.07	6.54	6.65	3.42	0.801	0.188	0.083	0.376	0.146

SU YILI (1983) YILLIK TOPLAM AKIM. 25.29 MİLYON M³, 395. MM, 12.5 LT/SN/KM².

(*) AKIM ÖLCÜSÜNÜN YAPILDIĞI GÜNLERİ GİSTERİR. Yıl içinde 2.Pik Akım Değeri 14.6 m³/sec. Tarihi 1.2.1983
Yıl içinde 3.Pik Akım Değeri 5.45 " Tarihi 6.4.1983

5 - GEDİZ HAVZASI
526 - ALAŞEHİR ÇAYI - BAKLACI

YERİ : (38° 02' 22" N - 38° 23' 28" E) Salihli - Alaşehir yolu üzerinde, Alaşehir'e 5 Km. mesafedeki köprüdedir.

YABİŞ ALANI : 1613.6 Km²

YAKLAŞIK KOT : 145 m.

GÖZLEM SÜRESİ : 10.Nisan.1969 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 2.167 m³/sn. (13 yıllık) 1983 Su yılında 1.029 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 22.8 m³/sn. (14. 9.1983)

1983 Su yılında en az akım : 0.001 " (28. 6.1983)

Gözlem süresinde en çok akım : 404. " (8. 2.1974)

Gözlem süresinde en az akım : Kuru (1.10.1970)

SEVİYE ÖLÇEĞİ : Ağırlıklı Eşel.

DÜŞÜNCELER : Akım durumu orta. Yıl içinde 3 ayrı anahtar eğrisi kullanılmış, 13 akım ölçüsü yapılmıştır.

13. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
480	0.000	530	2.12
490	0.080	540	3.60
500	0.260	550	5.65
510	0.590	580	15.0
520	1.20	600	25.0

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLUPAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.412	0.698	0.400	0.860	2.12	0.996	1.81	0.288	0.400	0.403	0.290	0.179
2	0.388	0.644	0.400	0.806	1.43	1.06	2.02	0.260	0.133	0.403	0.292	0.850
3	0.374	0.590	0.372	0.752	1.43	2.38	3.10	0.260	0.133	0.403	0.317	0.740
4	0.564	0.552	0.372	0.806	1.43	2.86	3.43	0.260	0.332	0.441	0.403	1.18
5	0.980	0.514	0.372	0.752	1.81	2.02	3.60	0.260	0.514	0.354	0.365	1.48
6	0.820	0.806	0.344	0.860	1.61	2.12	0.260	1.61	0.517	0.365	1.56	
7	0.692	0.644	0.372	0.928	1.36	1.45	2.64	0.400	1.8	0.479	0.317	1.64
8	0.564	0.438	0.372	0.860	1.28	1.45	2.64	0.316	0.850	0.317	0.234	1.71
9	0.456	0.400	0.438	0.806	1.36	1.45	2.64	0.316	1.07	0.328	0.479	1.79
10	0.412	0.400	0.438	0.806	1.06	1.45	2.64	0.316	1.07	0.328	0.479	1.94
11	0.456	0.400	0.438	0.752	0.996	1.45	2.25	0.260	0.403	0.441	0.237	0.057
12	0.692	0.372	0.476	0.698	0.928	1.45	3.60	0.288	0.365	0.317	0.237	16.3
13	1.34	0.372	0.314	0.644	0.860	1.92	2.77	0.288	0.328	0.441	0.365	0.441
14	2.60	0.372	0.314	0.644	0.996	2.12	1.92	0.344	0.208	0.223	0.328	22.8
15	0.996	0.400	0.352	0.644	0.996	1.71	1.61	0.344	0.328	0.223	0.365	16.1
16	0.644	0.372	0.514	0.860	1.06	1.92	1.61	0.344	0.328	0.441	0.403	0.110
17	0.928	0.400	0.476	1.13	1.28	1.81	2.38	0.316	0.479	0.479	0.328	0.008
18	0.860	0.438	0.514	1.06	1.45	1.45	2.77	0.260	0.441	0.179	0.260	0.012
19	0.752	0.644	0.590	1.06	1.28	1.36	1.53	0.176	0.441	0.223	0.208	0.012
20	0.698	0.698	0.590	0.996	1.20	1.45	1.71	0.197	0.441	0.164	0.252	0.016
21	0.644	0.698	0.590	1.06	1.13	1.53	0.644	0.400	0.517	0.179	0.365	0.012
22	0.698	0.698	0.552	1.06	1.06	1.45	3.98	0.372	0.517	0.150	0.328	0.012
23	0.752	0.590	0.552	1.45	1.45	1.36	2.51	0.288	0.479	0.150	0.479	0.016
24	0.698	0.552	0.552	1.28	1.45	1.45	1.92	0.239	0.403	0.164	0.630	0.020
25	0.698	0.552	0.444	1.20	1.36	1.36	1.81	0.176	0.441	0.164	0.685	0.016
26	0.752	0.514	0.860	1.13	1.20	1.71	0.316	0.176	0.479	0.150	0.479	0.020
27	0.806	0.514	0.860	1.13	1.13	2.64	0.400	0.140	0.441	0.179	0.194	0.044
28	0.806	0.476	0.928	1.06	1.06	2.51	1.28	0.080	0.441	0.194	0.905	0.016
29	0.752	0.476	0.996	1.06	1.06	2.25	0.372	0.140	0.403	0.179	1.02	0.012
30	0.698	0.438	1.13	0.996	1.06	2.02	0.316	0.140	0.441	0.179	0.905	0.008
31	0.752	---	1.06	1.28	---	1.53	---	0.140	---	0.208	0.441	---
TOPLAM	23.614	15.662	17.820	30.370	36.436	58.916	62.958	8.072	27.226	9.713	13.665	71.102
ORTALAMA	0.762	0.522	0.575	0.980	1.301	1.901	2.099	0.260	0.908	0.313	0.441	2.370
LT/SN/KM	0.472	0.324	0.356	0.607	0.806	1.18	1.30	0.161	0.563	0.194	0.273	1.47
AKIM MM.	1.26	0.839	0.954	1.63	1.95	3.15	3.37	0.432	1.46	0.520	0.732	3.81
10 N AKIM	2.04	1.35	1.54	2.62	3.15	5.09	5.44	0.697	2.35	0.839	1.18	6.14

SU YILI (1983) YILLIK TOPLAM AKIM. 32.45 MİLYON M³, 20.1 MM , 0.638 LT/SN/KM².

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÜSTERİR. Yıl içinde 2.Pik Akım Değeri 19.5 m³/sec. Tarihi 7.6.1983
Yıl içinde 3.Pik Akım Değeri 17.7 " Tarihi 13.10.1982

5 - GEDİZ HAVZASI
527 - GÖRDES ÇAYI - DARIBÜKÜ

YERİ : Akhisar - Gölümarmara yolunun 22. Km. sında (Regülâtöre 1 Km. kala) Gördes Çayı
membaına çıkan orman yolunun 8. Km. sındedir.

YAĞIŞ ALANI : 1467.6 Km²

YAKLAŞIK KOT : 140 m.

GÖZLEM SÜRESİ : 1.Ekim.1973 - 30.Eylül.1983

ORTALAMA AKIMLAR : Gözlem süresinde 7.336 m³/sn. (5 yıllık) 1983 Su yılında 2.553 m³/sn.

EN ÇOK VE EN AZ AKIMLAR 1983 Su yılında en çok akım : 170. m³/sn. (11. 7.1983)
1983 Su yılında en az akım : 0.038 " (9. 8.1983)
Gözlem süresinde en çok akım : 1555. " (15.12.1981)
Gözlem süresinde en az akım : 0.038 " (9. 8.1983)

SEVİYE ÖLÇEĞİ : Eşal ve Limnigraf.

DÜŞÜNCELER : Akım durumu iyi. Yıl içinde 2 ayrı anahtar eğrisi kullanılmış, 11 akım ölçüsü yapılmıştır.

6. Anahtar eğrisi (Seviyeler Cm. — Akımlar m³/Sn. dir.)

Seviye	Akım	Seviye	Akım
50	0.038	100	7.80
60	0.435	150	27.5
70	1.55	200	59.0
80	3.30	250	106.
90	5.30	300	170.

AKIMLAR 1 EKİM 1982'DEN 30 EYLÜL 1983'E KADAR VE SANİYEDE METRE-KUP OLUPAK

GÜN	EKİM	KASIM	ARALIK	OCAK	SUBAT	MART	NISAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL
1	0.200	0.276	0.316	3.30	7.30	6.55	2.98	1.73	4.30	0.117	1.10	2.117
2	0.200	0.276	0.316	2.78	14.2	8.09	2.78	1.55	2.35	0.117	0.435	0.117
3	0.200	0.276	0.316	2.60	11.8	6.34	2.60	1.44	1.33	0.237	0.336	0.117
4	0.400	0.276	0.316	2.60	16.6	9.25	2.43	1.33	1.33	0.276	0.276	0.117
5	0.400	0.276	0.316	2.60	11.4	8.67	2.25	0.993	1.44	1.55	0.197	0.117
6	0.300	0.356	0.316	2.78	11.1	7.80	7.30	0.881	1.33	0.658	0.157	0.117
7	0.300	0.356	0.316	2.43	9.34	7.30	25.0	0.881	1.22	0.256	0.078	0.117
8	0.300	0.316	0.316	1.90	8.38	7.05	14.6	0.881	1.10	0.276	0.078	0.117
9	0.300	0.316	0.316	1.44	8.09	7.05	10.4	0.881	1.22	0.237	0.038	0.117
10	0.300	0.316	0.316	1.33	7.55	7.30	8.38	0.881	0.993	0.435	0.038	0.117
11	0.200	0.316	0.316	1.22	7.05	7.55	6.30	0.993	0.993	17.7	0.038	0.117
12	0.200	0.316	0.316	1.22	6.80	7.55	6.90	1.10	0.881	2.95	0.038	0.117
13	0.900	0.316	0.316	1.22	6.80	7.05	4.50	1.10	0.770	1.22	0.038	0.117
14	1.00	0.316	0.316	1.22	6.55	6.80	4.50	1.10	0.770	0.770	0.038	0.117
15	0.900	0.316	0.316	1.10	6.33	6.30	4.30	1.10	0.881	0.435	0.038	0.117
16	1.72	0.316	0.316	8.67	6.30	6.05	4.30	1.10	0.881	0.356	0.356	0.117
17	0.86	0.316	0.316	13.2	6.30	6.05	4.10	0.993	0.993	0.316	0.356	0.117
18	1.33	0.316	0.316	8.96	7.30	5.10	3.90	3.90	0.993	0.770	0.276	0.117
19	1.33	0.316	0.316	7.80	6.80	4.50	3.70	2.43	0.881	1.55	0.237	0.117
20	1.22	0.316	0.316	7.30	6.30	4.70	3.70	2.25	0.881	0.356	0.237	0.157
21	0.993	0.316	4.10	8.96	6.05	4.70	3.70	2.95	0.770	0.237	0.237	0.157
22	0.547	0.316	3.13	22.1	5.80	4.70	3.50	3.70	0.770	0.197	0.237	0.157
23	0.435	0.316	2.78	11.4	7.80	4.30	3.30	2.78	0.658	0.157	0.197	0.157
24	0.395	0.316	2.60	8.96	7.55	4.10	2.95	2.25	0.658	0.157	0.157	0.157
25	0.356	0.316	3.70	7.80	6.30	3.90	2.63	1.55	0.435	0.117	0.197	0.157
26	0.316	0.316	5.55	7.05	5.55	3.70	2.43	1.33	0.395	0.117	0.197	0.157
27	0.316	0.316	4.90	6.30	5.30	3.70	2.25	1.10	0.316	0.378	0.197	0.157
28	0.316	0.316	3.70	5.55	5.30	3.50	2.25	0.993	0.237	0.078	0.197	0.157
29	0.276	0.316	3.13	5.10	5.30	3.30	2.08	0.881	0.117	0.078	0.157	0.157
30	0.276	0.316	4.10	4.50	5.30	3.13	1.90	2.60	0.117	0.993	0.157	0.157
31	0.276	---	4.10	4.30	---	2.78	---	7.80	---	1.33	0.117	---
TOPLAM	22.062	9.360	50.823	167.69	222.36	182.31	149.88	55.448	29.799	31.645	6.571	3.950
ORTALAMA	0.712	0.312	1.639	5.409	7.941	5.881	4.996	1.789	0.993	1.021	0.212	0.132
LT/SN/KM ²	0.485	0.213	1.12	3.69	5.41	4.01	3.40	1.22	0.677	0.696	0.144	0.090
AKIM MM.	1.30	0.551	2.99	9.87	13.1	10.7	8.82	3.26	1.75	1.86	0.387	0.233
10 M AKIM	1.91	0.809	4.39	14.5	19.2	15.8	12.9	4.79	2.57	2.73	0.568	0.341

SU YILI (1983) YILLIK TOPLAN AKIM. 80.52 MİLYON M³. 54.9 MM. 1.74 LT/SN/KM².

(*) AKIM ÖLÇÜSÜNÜN YAPILDIĞI GÜNLERİ GÖSTERİR. Yıl içinde 2.Pik Akım Değeri 49.6 m³/sec. Tarihi 18.5.1983
Yıl içinde 3.Pik Akım Değeri 42.6 " Tarihi 22.1.1983

Appendix D

Water Quality
Observation Stations
Data Sets

05-GEDİZ HAVZASI

BÖLGESİ : II.581ge-İZMİR
İSTASYON ADI VE YERİ : Gediz Nehri-Urganlı
İSTASYON NO : 05-02-00-002
AKIM GÖZLEM İSTASYONU : -

1983 YILI KALİTE GÖZLEMLERİ

[illegible]

05-GEDİZ HAVZASI

BÖLGESİ : II. Bölge-İZMİR
İSTASYON ADI VE YERİ : Kuru Çaya-Kıllık
İSTASYON NO : 05-02-00-003
AKIN GÜZLEM İSTASYONU : 510 (ZİE)

1983 YILI KALİTE GÖZLEMLERİ

[illegible]

05-GKD12 HAVZASI

BÖLÜMÜ : II.351ge-İZMİR

İSTASYON ADI VE YERİ : Gediz Nehri-Muradiye Köprüsü

ISTASYON NO : 05-02-00-005

AKIM GÜZLEM İSTASYONU : 5-25 (DSİ)

1983 YILI KALİTE GÖZLEMLERİ

[illegible]

05-GEDİZ HAVZASI

BÖLGESİ : 11. Bölge-İZMİR
İSTASYON ADI VE YERİ : Gediz Nehri-Menemen Köprüsü
İSTASYON NO : 05-02-00-006
AKIN GÖZLEM İSTASYONU : -

1983 YILI KALİTE GÖZLEMLERİ

[illegible]

Appendix E
Water Quality Classification
for
Surface Waters

Water Quality Classification for Surface Waters (Uslu & Türkman, 1987).

Water Quality Parameters	Water Quality Classes			
	I	II	III	IV
A. Physical and inorganic chemical parameters				
1. Temperature (°C)	25	25	30	>30
2. pH	6.5-8.5	6.5-8.5	6.0-9.0	out of range 6.0-9.0
3. Dissolved oxygen (mg/l)	8	6	3	<3
4. Dissolved oxygen saturation (%)	90	70	40	>40
5. Chloride (mg/l)	200	200	400	>400
6. Sulphate (mg/l)	200	200	400	>400
7. Ammonium nitrogen (mg/l)	0.2 ^a	1 ^a	2 ^a	>2
8. Nitrite nitrogen (mg/l)	0.002	0.01	0.05	>0.05
9. Nitrate nitrogen (mg/l)	5	10	20	>20
10. Total phosphorus (mg/l)	0.02	0.16	0.65	>0.65
11. Total dissolved solids (mg/l)	500	1500	5000	>5000
12. Color (Pt-Cu unit)	5	50	300	>300
13. Sodium (mg/l)	125	125	250	>250
B. Organic Parameters				
1. COD (mg/l)	25	50	70	>70
2. BOD ₅ (mg/l)	4	8	20	>20
3. Organic Carbon (mg/l)	5	8	12	>12
4. Total Kjeldahl nitrogen (mg/l)	0.5	1.5	5	>5
5. Emulsified oil and gres (mg/l)	0.02	0.3	0.5	>0.5
6. Alkyl benzene sulphonate	0.05	0.2	1	>1.5
C. Inorganic industrial pollution parameters				
1. Hg (µg/l)	0.1	0.5	2	>2
2. Cd (µg/l)	3	5	10	>10
3. Pb (µg/l)	10	20	50	>50
4. As (µg/l)	20	50	100	>100
5. Cu (µg/l)	20	50	200	>200
6. Cr (total) (µg/l)	20	50	200	>200
7. Cr (+6) (µg/l)	*	20	50	>50
8. Co (µg/l)	10	20	200	>200
9. Ni (µg/l)	20	50	200	>200
10. Zn (µg/l)	200	500	2000	>2000
11. CN (total) (µg/l)	10	50	100	>100
12. F (µg/l)	1000	1500	2000	>2000
13. Free chlorine (µg/l)	10	10	50	>50
14. Sulfide (µg/l)	2	2	10	>10
15. Fe (µg/l)	300	1000	5000	>5000
16. Mn (µg/l)	100	500	3000	>3000
17. B (µg/l)	1000	1000 ^c	1000	>1000
18. Se (µg/l)	10	10	20	>20
19. Ba (µg/l)	1000	2000	2000	>2000
20. Al (mg/l)	0.3	0.3	1	>1
21. Radioactivity (pCi/l)				
α-activity	1	10	10	>10
β-activity	10	100	100	>100
D. Organic industrial pollution parameters				
1. Phenolic matters (volatile) (mg/l)	0.002	0.01	0.1	>0.1
2. Mineral oil and derivatives (mg/l)	0.02	0.1	0.5	>0.5
3. Total pesticide (mg/l)	0.001	0.01	0.1	>0.1
E. Biological Parameters				
1. Fecal coliform (MS/100ml)	10	2000	20000	>20000

- (a) The concentration of free ammonium nitrogen should not be exceeded 0.02 mg NH₃-N/l related to the value of pH.
 - (b) One of the value between concentration and saturation of dissolved oxygen is enough to satisfy.
 - (c) The concentration of B should be lowered to 300 µg/l for irrigation of conscientious plants.
 - (d) The concentration limits should be lowered against chloride for irrigation of conscientious plants.
- * Excessive amount

Appendix F
Meteorological
Data Sets
of
DMI (State Meteorological Works)

Station Name: ALAŞEHİR													
Parameter	Observation period(year)	Months											
		1	2	3	4	5	6	7	8	9	10	11	12
A		There is no observations of pressure at this station.											
B	20	6.6	8.1	10.5	15.5	20.7	25.0	27.8	26.8	23.0	16.5	12.3	7.9
C	25	23.0	25.0	30.9	35.6	39.2	41.0	42.2	42.0	39.3	37.0	31.1	23.1
D	25	-7.5	-7.5	-5.1	-0.9	3.1	7.8	11.5	10.0	6.5	0.0	-3.5	-8.0
E	22	4.4	4.2	5.5	6.8	9.3	15.0	22.9	24.0	19.5	12.9	7.2	5.2
F	22	15.4	14.1	15.8	16.0	18.1	13.7	7.8	7.0	9.8	14.3	14.5	15.3
G	22	11.2	9.9	9.7	7.0	3.5	1.3	0.2	0.0	0.7	3.8	8.3	10.4
H	22	1.9	1.9	1.9	1.9	1.7	1.8	1.7	1.5	1.4	1.6	1.7	1.9
I	30	8 SE	8SW	8NW	8SW	7 W	8NW	8NW	8SW	7NW	7NW	8SE	8NE
J	20	N	N	NW	W	W	W	W	NW	W	N	N	N
K	50	73.0	74.6	57.0	31.8	36.9	18.5	8.2	4.7	9.6	32.1	57.0	84.4
													487.5

- A: Average actual pressure (mbar)
B: Average temperature (°C)
C: Maximum temperature (°C)
D: Minimum temperature (°C)
E: The number of days that have minimum cloudiness
F: The number of days that have average cloudiness
G: The number of days that have maximum cloudiness
H: Average wind speed (m/s)
I: Maximum wind and its direction
J: Dominant wind direction
K: Average height of rain (mm)

Station Name: AKHISAR														
	Observation period(year)	Months												Annual Average
		1	2	3	4	5	6	7	8	9	10	11	12	
A	54	1005.9	1005.0	1004.2	1002.4	1001.8	1000.7	998.8	999.3	1003.1	1006.0	1006.9	1006.4	1003.4
B	54	6.1	7.2	9.5	14.4	19.6	24.2	26.6	26.2	22.2	16.6	11.4	7.8	16.0
C	54	22.3	24.7	30.3	33.6	39.2	42.8	44.3	44.6	40.7	37.5	30.7	26.2	44.6
D	54	-13.6	-9.2	-7.4	-3.0	2.0	4.0	9.2	8.4	4.8	-3.0	-10.7	-10.8	-13.6
E	54	4.6	4.5	5.6	6.0	7.3	14.3	24.1	25.0	20.2	12.5	6.5	5.0	135.6
F	54	14.9	15.4	17.2	18.3	20.1	14.8	6.7	5.8	9.1	15.1	17.0	16.4	170.8
G	54	11.5	8.4	8.1	5.6	3.3	0.7	0.1	0.2	0.6	3.4	6.4	9.6	57.9
H	47	2.1	2.4	2.4	2.0	2.0	2.4	3.3	3.2	2.5	2.0	1.4	1.6	2.3
I	47	29.2	32.2	32.5	28.6	27.3	25.2	24.8	26.0	24.0	27.1	25.7	32.2	32.5
J	42	N	N	N	WSW	NNW	SW	N	SSE	WNW	SSE	SSW	WSW	WNW
K	61	104.1	81.7	64.7	47.8	34.6	14.1	4.0	4.3	11.4	38.8	73.9	115.4	594.8

- A: Average actual pressure (mbar)
B: Average temperature (°C)
C: Maximum temperature (°C)
D: Minimum temperature (°C)
E: The number of days that have minimum cloudiness
F: The number of days that have average cloudiness
G: The number of days that have maximum cloudiness
H: Average wind speed (m/s)
I: Maximum wind and its direction
J: Dominant wind direction
K: Average height of rain (mm)

Station Name: SALIHLI														
	Observation period(year)	Months												Annual Average
		1	2	3	4	5	6	7	8	9	10	11	12	
A	23	1005.5	1003.8	1002.8	1000.9	1001.1	999.6	998.2	998.9	1002.3	1005.4	1006.1	1005.9	1002.5
B	26	6.4	7.5	10.4	15.3	20.4	24.6	26.7	26.0	22.2	16.1	11.2	7.9	16.2
C	26	24.2	24.1	31.0	37.2	38.6	41.0	43.2	41.6	38.7	36.4	29.8	24.5	43.2
D	26	-8.0	-10.2	-5.3	0.0	2.4	9.4	10.7	9.8	6.0	-0.3	-5.2	-6.0	-10.2
E	26	5.9	5.0	6.9	6.3	10.7	17.6	24.2	24.8	21.6	13.7	8.8	6.2	151.7
F	26	17.8	16.7	17.3	18.5	18.4	11.7	6.7	6.1	8.0	14.4	16.4	17.8	169.9
G	26	7.3	6.5	6.7	5.2	1.8	0.8	0.1	0.1	0.3	2.9	4.8	7.4	44.0
H	22	1.5	1.7	1.7	1.8	2.0	1.9	2.1	2.0	1.6	1.3	1.2	1.4	1.7
I	22	26.0	27.0	32.0	27.6	20.6	28.0	24.3	16.8	26.7	19.9	26.9	31.6	32.0
J	22	W	WSW	WSW	W	WSW	W	WSW	W	W	W	W	ESE	WSW
K	51	79.5	67.9	59.2	39.2	33.5	17.3	5.8	4.4	10.6	34.9	55.8	82.5	490.7

- A: Average actual pressure (mbar)
B: Average temperature (°C)
C: Maximum temperature (°C)
D: Minimum temperature (°C)
E: The number of days that have minimum cloudiness
F: The number of days that have average cloudiness
G: The number of days that have maximum cloudiness
H: Average wind speed (m/s)
I: Maximum wind and its direction
J: Dominant wind direction
K: Average height of rain (mm)

Station Name: MANISA														
	Observation period(year)	Months												
		1	2	3	4	5	6	7	8	9	10	11	12	Annual Average
A	61	1009.0	1007.6	1007.0	1005.3	1004.9	1003.7	1002.0	1002.5	1006.2	1009.0	1009.8	1009.3	1006.4
B	61	6.8	8.0	10.4	15.1	20.1	25.0	27.6	27.2	23.1	17.6	12.3	8.4	16.9
C	61	23.3	24.8	33.5	34.6	39.5	41.8	44.0	44.5	40.1	36.0	29.9	26.4	44.5
D	61	-17.5	-10.9	-6.7	-2.7	2.0	7.4	10.5	11.2	3.3	-0.9	-7.3	-9.9	-17.5
E	61	3.8	3.6	5.3	5.4	7.4	14.2	23.0	24.1	19.4	11.1	5.1	4.0	126.4
F	61	15.5	15.9	17.1	19.2	20.3	15.1	7.6	6.8	9.7	16.2	18.6	16.6	178.6
G	61	11.6	8.8	8.6	5.5	3.3	0.6	0.1	0.0	0.7	3.9	6.2	10.4	59.7
H	56	2.3	2.5	2.5	2.3	2.0	2.1	2.4	2.4	2.0	1.8	1.8	1.9	2.2
I	56	39.1	35.5	38.4	34.6	26.4	29.0	27.2	20.4	26.4	29.6	32.7	41.2	41.2
J	40	S	S	SW	S	SW	SSW	SW	SW	SW	SW	S	S	S
K	61	E	E	E	E	E	E	E	E	E	E	E	E	E
		128.8	106.2	78.6	55.8	40.0	15.1	6.4	4.6	15.8	50.0	90.9	147.8	740.0

- A: Average actual pressure (mbar)
B: Average temperature (°C)
C: Maximum temperature (°C)
D: Minimum temperature (°C)
E: The number of days that have minimum cloudiness
F: The number of days that have average cloudiness
G: The number of days that have maximum cloudiness
H: Average wind speed (m/s)
I: Maximum wind and its direction
J: Dominant wind direction
K: Average height of rain (mm)