UNIVERSITY OF THE WITWATERSRAND,
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DEPARTMENT OF CIVIL ENGINEERING

ADVECTIVE WATER QUALITY MODEL FOR URBAN WATERCOURSES

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FOR URBAN WATERCOURSES

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

September 1991

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Musa Stefane Furumele

17th day of September 1991

ABSTRACT

As has happened throughout the world, environmental and water quality problems related to developing urban and industrial areas and associated accumulation of waste in built-up areas were the main factors in contributing to sanitary awareness in South Africa. The dwindling water resources and persistent deterioration of water quality, more severely in urban areas, necessitates the review the current practice of stormwater management in South Africa. Reliable stormwater drainage models evaluating both the water quantity and quality could be essendial in confronting the prevailing pollution problems. The objective of this project was conceived to be the development of a system for the simulation of water quality in urban watercourses.

A personal computer compatible model for joint transposition of hydrograph and pollutographs in open channels was developed. The model comprises an operational data handling facility, a user friendly and interactive interface.

The study revealed that:

- Urban and Industrial development results in complication of the urban water system.

- Single objectivity approaches in management of urban watercourses are outdated.

- The proposed model is capable of simultaneously routing flood and pollutant constituent waves in open channels.

- Understanding of aspects of the water quality in urban watercourse can be greatly enhanced by the proposed model.

The following recommendations were henceforth made:

- Detailed study of the nature, quantity and sources of pollutants in the urban water system.
- Sophisticated (dynamic wave, supercritical flow, complicated geometry) hydrodynamic model should be considered.
- Biological and chemical process in the urban watercourse be incorporated.
- Linking of the water quality model to the storm water drainage model.

DEDICATION

In memory of my late grandparents

Paulus Stefane

and

Noria Pyalu

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CHAPTER 1

1.0 INTRODUCTION

1.1 General

The fundamental importance of water for life on earth, needs minimal justification. Indeed, modern urban and industrial developments would scarcely be possible without an adequate supply of the right degree of purity. It is obviously of primary importance that water should be available to mankind in sufficient quantity. But scarcely of less significance is the quality of the water. It is this connection, that the pollution of many watercourses looms as a problem of the first magnitude.

Transition to urban environment can have a dramatic influence, not only to the quantity but to the quality of runoff as well. The continuing coalescence and expansion of our urban areas into metropolis could stress our environment beyond tolerable limits. Aqueous discharges in form of sewage and wastewater usually accompany urban and industrial developments.

While much can be done towards keeping undesirable effluent out of watercourses by controlling the pollution at a source (varying degrees of treatment, legal constraint for discharging), it must be appreciated that urban watercourses will remain polluted.

With the 20th Century in its closing decade, South Africa is no exception to the world-wide watercourse pollution problems. Stormwater runoff, consisting of significantly high concentration of pollutants, is not treated prior to being discharged into watercourses. Moreover, in many densely populated residential areas, such as Soweto, sewage reticulation systems frequently malfunction due to sewer blockages, therefore redirecting raw sewage into stormwater inlets. All these pollutants thus end up in watercourses.

Before the era of environmental concern, the pollution effects of urban development were largely ignored in applying traditional drainage methods. The persistent deterioration in water quality necessitated multi-objective approaches in planning, design and management of urban watercourses.

1.2 Overview of water quality models in watercourses

A survey of relevant literature was undertaken, to identify previous work by other researchers. The survey is by no means a complete overview of all the work in the field, but a highlight of important work contributing directly to the development of an appropriate water quality model.

The behaviour of an urban watercourse, would probably fall in the category of river modelling, hence the survey examined riverine quality models in general. Quality models in this category are adequately covered by one-dimensional models.

A study of river water quality in South Africa, was presented by Arnold (*1980*). He developed a suite of programs, incorporating wastewater treatment and river water quality, which were implemented on main-frame computers. The water quality model was based on the well-known Streeter-Phelps equation. An explicit finite difference scheme was employed to obtain solutions. Simplifications such as uniform channel, constant area and flow rate are inherent in the model.

Mileikowsky (*1980*), also in South Africa, developed a numerical model for simulating current and future daily fluctuations of salinity in the Vaal barrage. The model is essentially a one-dimensional cell-type representation of the Barrage reservoir. Basic input was obtained from other models, such as the far field model, which simulates behaviour of the comprehensive reservoir system, wash-off model, which generates tributary inflows in both quantity and quality. The model uses a finite difference scheme and the tri-diagonal matrix to calculate solutions.

Another South African model was presented by Fijen and Huizinga (*1987*). A one-dimensional hydrodynamic and water quality computer program was developed and used to study the physical, biological and ecological aspects of the Sunday river estuary. Water levels, flows and salinity distributions in this river were modelled. The hydrodynamic routines employed, were the long-wave equations of momentum and continuity (*Dronkers, 1969*). For water quality computation, the advection-dispersion equation (*Fischer et al, 1979, Koussis et al, 1984*) was employed. An explicit leapfrog finite difference scheme was adopted for the solutions of both equations.

The most comprehensive study of water quality in an urban watercourse was undertaken by Moodie (*1979*). He developed a suite of hydrologic/hydraulic and water quality computer programs. The models were based on the identification of problems in Gardiners Creek, a typical urban watercourse located in the suburb of Melbourne, Australia. The variable Parameter Muskingum - Cunge method of flood routing, based on the work of Price (*1977*), was used for the hydrologic/hydraulic sub-model. This was solved using a four point explicit finite difference scheme. Two water quality sub-models were also developed, based on the simple mass balance and the Streeter-Phelps equations.

A dynamic water quality model for storm induced flows in rivers was developed by Bedford et al (*1983*). The model comprises a hydrodynamic portion based on the full dynamic equation and was solved utilizing the four-point implicit Newton-Raphson procedure, while the water quality code was formulated with the Holley-Preissmann's non-linear formulation. Keefer and Jobson (*1978*), also presented the most analogous to this model. However, theirs was more general using a linearised four-point implicit hydrodynamic solution and the modified six-point Stone and Brain pollutant solution. The model was originally constructed and implemented for the Water Quality Analysis and Surveillance section of the Ohio Environmental Protection Agency.

In general riverine water quality modelling is the combined effect of advection, dispersion and biochemical reaction. The mass transport of pollutants has traditionally been represented by the Advective-Dispersion (AD) equation, whereas the biochemical activities by the Streeter-Phelps equation.

Discrepancies between observed dispersion in rivers and that predicted using the classical AD equation, have been acknowledged and explained (*Liu and Cheng, 1980; Sabol and Nordin, 1978*). Some investigators have therefore proposed other models to predict mass transport in natural streams and rivers:

- Examples are those given by Thackston and Schnelle (*1970*), Jobson and Yotsukura (*1972*), McQuivey and Keefer (*1974, 1976*), Pedersen (*1977*), Sabol and Nordin (*1978*), Beltaos (*1978*), and Liu (*1980*).

- Some of the alternative models are expansions of the AD equation and include entrapment in dead zones (*Pedersen, 1977*), or multi-dimensionality (*Jobson and Yotsokura, 1972*), or time-dependent (or distance) dispersion co-efficients (*Liu and Cheng, 1980*).

- Stefan and Demetracopoulos (*1981*) presented the most radical deviation from the classical AD equation, the cells-in-series (CIS) formulation. The CIS model assumes that the river is composed of a sequence of elements of equal volume, called cells. Complete mixing occurs on each cell.

- Phelps (*1944*) described much of the early knowledge of the process of stream pollution, as well as detailing the development of the widely used Streeter-Phelps equations and their analytical solution in the form of the dissolved oxygen sag equation.

- Velz (*1970*), proposed a "rational method" for determining the dissolved oxygen sag curve which he considered preferable to the simplified dissolved oxygen sag equations of Streeter-Phelps.

- Thomann (*1972*) developed analytical solutions to include factors such as dispersion, nitrification, algal photosynthesis and respiration, bethal demand, etc. in a systems approach, as did Rinaldi et al (*1979*). Analytical solutions are also used by Liu (*1962*), Gunnerson and Bailey (*1963*), Holley (*1969*) and Fan et al (*1971*), whereas Chevereau (*1973*) used numerical techniques to solve the equations and used COD to represent the ultimate BOD of the water.

- The two-step explicit finite difference method used by Chevereau was initially developed for the BOD-DO equations by Dresnack and Dobbins (*1968*) to overcome certain difficulties inherent in the standard finite difference methods.

- Bella and Dobbins (*1968*) also studied the difference modelling of stream pollution in great detail.

- Beck and Young (*1975*) developed a lumped parameter BOD-DO model conceptualised by a transportation delay system plus a continuously stirred tank reactor. An important aspect of their model was that it used daily BOD data, thereby recognising the difficulties involved in obtaining more frequent data over long time periods.

- De Boer (*1976, 1979*) used the method of characteristics in a moving cell model of the dissolved oxygen and other quality parameters, thereby avoiding the problem of numerical dispersion.

- Dobbins (*1964*) investigated methods of determining the various constants in the BOD-DO equations and proposed a rational theory for estimating the surface reaeration rate. Camp (*1965*) on the other hand found that reaeration was small compared to photosynthetic production of dissolved oxygen, and also concluded that the removal of BOD by settling could be very large compared to the removal by biochemical oxidation. O'Connor and Di Toro (*1970*) studies the diurnal variation of photosynthetic production of dissolved oxygen and developed an oxygen balance model that includes this effect.

- Increases in DO during the night were reported by Gunnerson and Bailey (*1963*) and this was attributed to variations in the algal respiration rate.

- Edberg and Hofsten (*1973*) described in-situ and laboratory tests on oxygen uptake of bottom sediments and found that the latter gave consistently lower values than the former. A number of models for estimating reaeration rates have been proposed (*O' Connor and Dobbins, 1958; Churchill and Buckingham, 1962; Bansal, 1973; Foree, 1976*).

Major points to note from the brief literature survey are:

- Numerous authors have developed water quality models based on the one-dimensional Advective-Dispersion and the Streeter-Phelps equations.

- Extensive work has been undertaken on the biochemical aspects of riverine water quality.

- South Africa trails behind in modelling water quality in watercourses.

- Finite difference schemes have been utilized extensively to evaluate solutions.

- Most models developed in South Africa have been implemented on main-frame computers, which are costly and not user friendly.

1.3 Development of a water quality model on a Personal Computer

Water quality simulation in watercourses is a complex multi-disciplinary undertaking involving Hydrology, Hydraulics, Mathematics, Biology, Chemistry and even Numerical methods. The process necessitates mathematical formulation of the system's behaviour resulting in tedious calculations. The computation burden can be drastically reduced in the advent of efficient, high speed, digital computing systems.

Through the years a large number of water quality models have been developed by various researchers, many of them proprietary. In general, the models were main-frame orientated. Main-frame practices suffer from a number of disadvantages, such as accessibility, cost, interaction with the user and graphical representation.

Over the past two decades, the power and the capacity of personal computers has been continually enhanced and expanded by advances in micro computer technology. These developments have demonstrated that it is not only possible, but also feasible to develop water quality models for watercourses. To ensure operational systems, the following attributes would be necessary: simplicity, consistency, completeness, robustness, economical and independence.

1.4 Conclusions

The declining water quality, coupled with South Africa's water resources plight, emphasises multi-objective approaches for urban watercourses.

It therefore becomes clear that a comprehensive suite of personal computer orientated programs could be a viable aid in understanding water quality in urban watercourses.

In view of the foregoing, the aims of this study were set out as follows:

- To develop a model which would simulate water quality in urban watercourses.
- The model to be personal computer compatible.

- The model to be able to simultaneously compute transposition of hydrographs and pollutographs in watercourses.

- The model to incorporate all attributes mentioned earlier : simplicity, consistency, completeness, robustness, performance and independence.

- The model to have an operational data handling structure, user friendly and interactive.

The methodology used to achieve the abovementioned aims is outlined below:

- Identify aspects of the urban water system

- Mathematical formulation of the model

- Choice of an appropriate numerical scheme for solutions

- Development of a suite of computer programs

- Verification of the model.

CHAPTER 2

2.0 ASPECTS OF THE URBAN WATER SYSTEM

2.1 Urban hydrology

Hydrology, in general, may be defined as (*Universities Council on Water Resources, 1967*) : "the physical science that treats the waters of the earth, their occurrence, circulation and distribution, their chemical and physical properties, and the reaction of the environment, including living things, on those waters". It is an interdisciplinary subject, embracing physical, chemical, biological and applied sciences, and concerns the spatial and temporal distribution as well as the movement of water in all its forms. The latter is implicit in the concept of the hydrological cycle.

The era of industrial revolution and growth of manufacturing industries has brought people together. The establishment of factories meant that livelihoods become dependent on employment rather than on subsistence farming through self endeavour. This process of urbanization, the congregation of people together to live in towns, has led to manipulation of the environment, and therefore the landscape of the hydrological cycle. Wildscape has been cleared for agriculture, forests have been felled, swamps have been drained and most important, towns and cities have been created in what were once rural areas. Over the last three decades emphasis has been placed on the hydrology of land-use changes in the general, and more recently the subject of urban hydrology.

Urban hydrology can be defined as the study of the hydrological process occurring within the urban environment. A detail conception of the urban hydrological cycle is indicated on Figure 2.1 below.

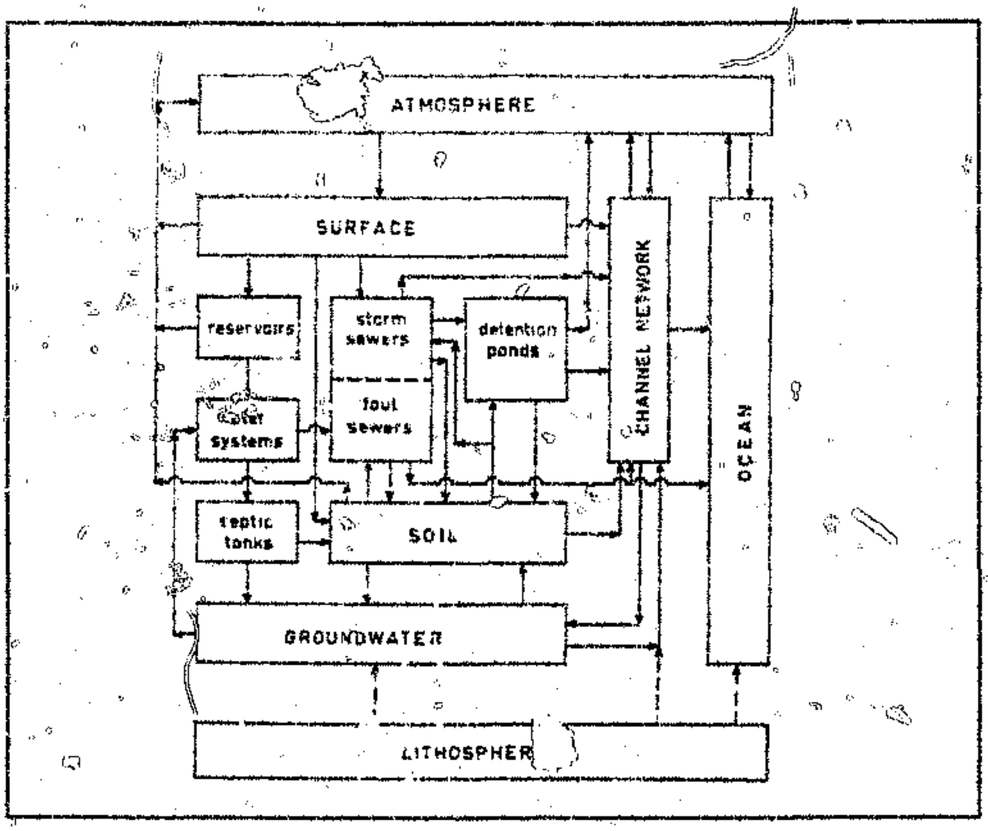

Figure 2.1 **Urban hydrological cycle**
(Adapted from Hengeveld and Vocht, 1982)

The continuing expansion of our urban area results in hydrological problems. Four major problems have been identified (*Hengeveld and Vocht, 1982*):

- Provision for water resources adequate both in quantity and quality
- Need for appropriate flood control measures

- Disposal of water-borne waste without impairing the quality of local watercourses

- Changes in the urban microclimate

The project entails the modelling of water quality in urban watercourses, henceforth the degradation of the quality of water in urban areas is of interest. The following sub-sections cover quality characteristics of urban runoff and sources of pollution.

2.2 Quality characteristics of urban runoff

In the past two decades, considerable research and documentation of urban stormwater runoff has been undertaken overseas, in particular the United States of America and Australia. In line with this trend, Green et al (*1986*), undertook an exploratory survey of stormwater pollution in two South African urban catchments (Hillbrow and Montgomery Park).

Pollution in urban watercourses result from domestic sewage, urban runoff, industrial wastewater and possible atmospheric fall out. As treatment of domestic sewage and industrial wastewater are gradually receiving attention, urban stormwater runoff is identified as the main culprit for pollution. Santor and Boyd (*1972*) indicated that runoff may consist of highly concentrated pollutants rather than raw sewage.

Stephenson (*1982*) presented a range of measured water quality parameters, obtained from various sources and these are indicated in Table 2.1 overleaf:

Table 2.1 **Urban runoff quality characteristics***

Characteristics		Low	Average	High
BOD	(mg/l)	10	30	500
Suspended Solids	(mg/l)	20	200	10 000
Coliform	(No/100ml)	50	10 000	100 x 10^6
Total chlorides	(mg/l)	10	200	10 000
Total dissolved solids	(mg/l)	300	1 000	10 000
pH	(mg/l)	5.3	7	8.7
Nitrogen	(mg/l)	1	3	100
Phosphate	(mg/l)	0.1	1	50
Phenols	(mg/l)	0		0.2
Oils	(mg/l)	0		110
Lead	(mg/l)	0		2

* *Adapted from Stephenson (1982)*

The above values are not representative of any particular catchment, but an indication of quality characteristics of urban runoff.

Pollution is measured in terms of concentrations. For instance, suspended solids such as silt are measured per litre (mg/l). A specific nutrient like nitrate is measured in terms of the mg/l of nitrogen. The total nitrogen content may comprise of organic nitrogen, ammonia, nitrogen, nitrite and nitrate. Phosphate, also a nutrient, in the correct proportion in the presence of nitrate can support aquatic life.

2.3 Sources of pollution

Pollution of an urban watercourse can broadly be attributed to surface washoff, atmospheric deposition, domestic sewage and industrial wastewater.

Pollution sources other than domestic sewage and industrial wastewater will be discussed here. Simpson and Kemp (*1982*), observed that atmospheric deposition and surface washoff were responsible for 30% of suspended solids, 15% of phosphorus, 19% of nitrates, and 37% of soluble phosphorus and for all soluble nitrogen.

Horkeby and Malmquist (*1977*) also attributed the presence of arsenic, cadmium, chromium, mercury, tin, vanadium and lead in urban stormwater runoff to atmospheric deposition. Rainfall itself was found by Black (*1980*) to be the source of nitrate loads.

Vehicle exhausts, wearing of tyres, asphalt and corrosion of vehicles and buildings, were also identified as sources of heavy metals.

2.4 Conclusions

The process of urbanisation results in the complication of the global hydrological cycle. The consequence inevitably includes degradation of water quality.

The characteristics of pollution in an urban watercourse comprises of highly concentrated loads. In the case of South Africa, this could worsen the countries water resources problem. Recreational amenities could be lost and also a threat to aquatic life is posed.

As the urban watercourse is part of a complex natural river system an appreciation of its pollution impact would lead to a better understanding of the global river pollution problem.

Water quality is an important factor in many uses of water. Agriculture for instance, can accommodate nutrients, but not those with high salt contents. For domestic water supplies, coliform count, colour and taste are important parameters. For recreational purposes, similar criteria are often applied.

CHAPTER 3

3.0 MATHEMATICAL FORMULATION OF AN ADVECTIVE WATER QUALITY MODEL.

3.1 Transport equation rationale

The overriding consideration that guided formulation of the model (in line with *Bedford et al: 1983*), was that very sharp spatial and temporal gradients of flow, elevation and pollutant concentrations, are propelled through reaches of rapidly varying cross-sectional areas during flooding events. Transport being dominated by advection and pollutant concentrations are more a consequence of it rather than dispersion or biochemical reaction.

It follows that the model must:

- be dynamic,
- account for flow, elevation and transport changes,
- include the direction interaction of flow and, elevation on pollutant distribution,
- be applicable to channels of arbitrary shape and slope.

The model would therefore, consist of two sets of area averaged equations, namely, hydrodynamic equations depicting movement of flood waves and the pollutant transport equations.

The results obtained from the hydrodynamic sub-model would then be imposed as input data for pollutant transport sub-model, hence obtaining results for the complete the water quality model.

3.2 Governing transport equations

3.2.1 Hydrodynamics

Mathematical flood routing methods currently available may be broadly classified into process-type models, usually referred to as "hydraulic methods", and those using a conceptual or system approach, often called "hydrologic methods".

As a result of drawbacks and over-simplifications of hydrologic methods, Engineers have turned to the Saint Venant equation. These equations are, however, also complicated for analytical solutions. Thus, the Saint Venant equations have in turn been simplified, and the resulting equations designate the now-called **dynamic, diffusion** and the **kinematic models.**

The complete dynamic model, which retains all the terms is the most accurate and reliable, as well as most demanding on computer resources. The diffusion and kinematic models on the other hand have simpler equations and thus are easier to program.

Numerous authors *(Ponce et al 1978; Weinman and Laurenson, 1980; Stephenson, 1980; Kolovopoulos and Stephenson, 1988; Kolovopoulos, 1988)* have also investigated the applicability and performance of the kinematic and diffusion model.

The kinematic models are limited to relatively steep watercourses where backwater effects are negligible and also to mildly sloped hydrographs. The diffusion models have a far greater range of applicability than kinematic models.

The diffusion model has been implemented successfully for channel routing, whereas overland flow can be described realistically using the kinematic model.

In compliance with aims of this study, the simpler but realistic **diffusion model** was found to be appropriate in representing the movement of flood waves.

a) *One-dimensional unsteady flow in open channels*

The derivation of the equations is routine (*Yen, 1973; Henderson, 1966; Chow, 1959; Dronkers, 1969*) and will not be repeated herein. Three partial different equations were derived representing conservation of mass (continuity), momentum and energy.

Two of the derived equations to be used herein are:

Continuity equation:

$$\partial Q/\partial x + B(z)\ \partial h/\partial t = q \qquad (3.1)$$

Momentum equation:

$$\partial Q/\partial t + \partial/\partial x\ \{(Q^2)/A(z)\} + \{gA(z)\ \partial h/\partial x - gA(z)S_o\} + gA(z)\ S_f = 0 \qquad (3.2)$$

(4) (3) (2) (1)

where:

(1) = Flow Resistance

(2) = Gravity

(3) = Bernoulli

(4) = Inertia

and:

Q	=	flow rate in x-direction (m^3/s)
q	=	lateral inflow (m^3/s)
x	=	distance along the channel (m)
B(z)	=	water surface width (m)
A(z)	=	cross-sectional area of channel (m^2)
h	=	water surface elevation (m)
t	=	time (s)
g	=	gravitational acceleration (m/s^2)
S_f	=	friction resistance (slope) (m/m)
S_o	=	bed slope (m/m)

In the continuity equation the lateral inflow (q) was ignored in this study. Inflow (or outflow) continuously distributed along the watercourse is seldom considered in mathematical modelling of rivers. The most common situations in which such lateral discharge is to be considered are related to hydrological phenomena such as; evaporation, rainfall and infiltration. The mild climate in South Africa make these phenomena mild, and thus can be neglected in modelling. Tributaries and effluents could be represented by point inflows or outflows rather than by continuous lateral discharge (*Cunge et al, 1980*).

In the **diffusion model** approximation of the Saint Venant equations, the local and convective terms in the momentum equation terms are neglected. Thus the equation 3.2 becomes:

$$gA\,\partial h/\partial x + gA(S_f - S_0) = 0 \qquad \text{.......... (3.2.1)}$$

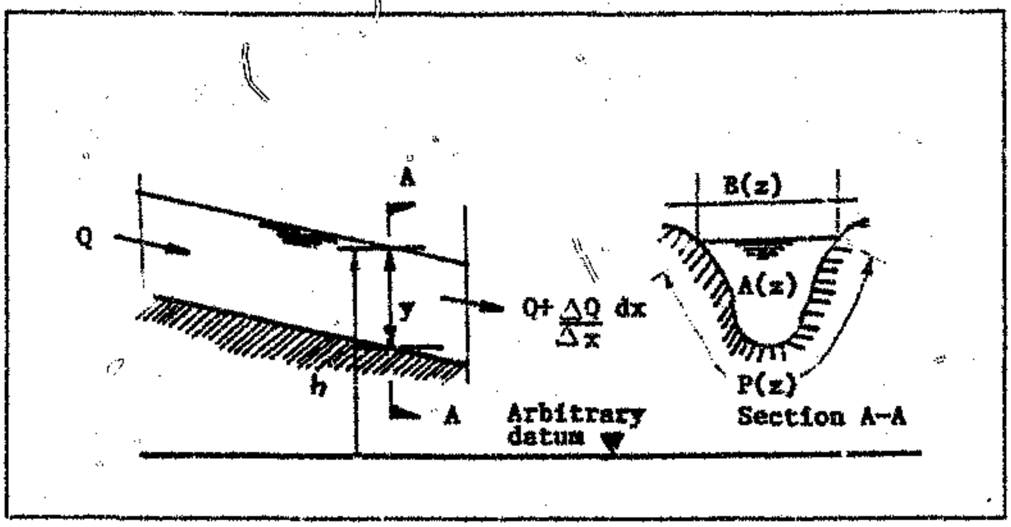

Figure 3.1 **Definition sketch of a typical cross-section**

b) *Flow resistance*

The resistance of flow due to shear forces mainly arising from bed friction and the influence of wind is represented by a number of empirical laws.

In the momentum equation the friction slope "S_f" was represented by the Manning's formula. The influence of wind was assumed to be negligible. Alternatively other friction formulae such as Darcy-Weisbach's or Chezy's may be used, however, the Manning's formula has proved most reliable in practice (*Henderson, 1967*) and popular amongst engineers in South Africa.

Manning's formula:

$$Q = \{A R^{2/3} S_f^{1/2}\} / n \qquad \text{(3.3)}$$

where

n = Manning's roughness coefficient

R = hydraulic radius (A/P)

P = wetted perimeter (m)

The above equation can be rewritten in the form:

$$Q = K(z) S_f^{1/2} \qquad \text{(3.4)}$$

where

$$K(z) = \{A R^{2/3}\} / n = \text{conveyance factor}$$

Inversely friction slope (resistance)

$$S_f = Q^2/K^2(z) = Q|Q| / K^2(z) \qquad \text{(3.5)}$$

3.2.2 Pollutant transport

The overview of water quality models presented in Chapter 1 "highlighted" various methods of modelling pollution. For this study the **one-dimensional mass balance equation** allowing for **advection** and **decay** was chosen.

Rinaldi et al (*1979*) also noted that a fluid could be looked at from several points of view. One possibility, for instance, being the molecular approach, which considers the fluid as a huge number of molecules moving around and colliding with each other in vacuum. The other being the continuum approach (mass balance) which is best suited to river quality considerations. Following the latter approach each point in space is associated with the value of the property considered (for example energy, momentum, bacterial mass) over a small reference volume.

The advantage of using the continuum approach is that a heterogenous multicomponent fluid can be described as being composed of different continua, interacting with each other and occupying the same position in space at the same instant of time, so that properties of any of these continua may be assigned to every point of the space.

a) *One-dimensional pollutant transport in open channels*

Stephenson (*1988*) presented the derivation of the basic one-dimensional mass balance equation allowing for dispersion, decay and sources or sinks.

The resulting equation is as follows:

$$\partial C/\partial t + K_p C + (C/A(z)(\partial Q/\partial x)) - 1/A(z)\ \partial/\partial x\{(AE\ \partial C/\partial x)\} - S = 0 \quad \text{.......... (3.6)}$$

(5) (4) (3) (2) (1)

where:

(1) = Source

(2) = Dispersion

(3) = Advection

(4) = Decay Rate

(5) = Pollutant Concentration Rate of Change

and:

A(z)	=	cross-sectional area of channel (m^2)
Q	=	flow rate in x-direction (m^3/s)
C	=	pollutant concentration (mg/l)
E	=	longitudinal dispersion co-efficient (m^2/s)
K_p	=	pollutant decay rate (s^{-1})
x	=	distance along channel (m)
t	=	time (s)

Normally dispersion is negligible in urban watercourses as they are relatively short and to a large extent channelized (*Stephenson, 1990*), and therefore was not considered in this study. Equation 3.6 thus becomes:

$$\partial C/\partial t + K_p C + (C/A)(\partial Q/\partial x) + V\partial C/\partial x = 0 \quad \text{.......... (3.6.1)}$$

where:

$V = Q/A$

CHAPTER 4

4.0 NUMERICAL SCHEMES FOR SOLUTION OF TRANSPORT EQUATIONS

4.1 General

The transport equations comprises a set of non-linear partial differential equations. The complexity of analytically solving these equations, makes it necessary that consideration be given to use of numerical techniques to obtain approximate solutions.

All published numerical techniques are based in the procedure of discretising the equations and then solving them in conjunction with suitable boundary conditions. **Discretization** is the procedure of representing a continuous variable by discreet values at specific points in space or time, or both (*ASCE, Task Committee on Glossary, 1982*).

4.2 Summary of methods

Numerical solution methods can be categorised into three classes; namely the **finite element method**, **method of characteristics** and **finite difference method** (*Cunge et al, 1980*). An outline of these methods is covered in the following sub-section.

4.2.1 Finite element methods

In recent years, the finite element method (FEM) has become increasingly popular in almost every engineering field. In fluid mechanics and ground water hydraulics the method has been extensively applied.

The method has also found application in various problems of surface waters, such as lake circulation, thermal loading and flows in shallow waters (*Cheng, 1978; Connor and Brebbia, 1976*).

Cooley and Moin (*1976*), Smith and Cheng (*1976*) extended the application of the method to unsteady open channel flows. Using it, the equations of a numerical model are solved by dividing the spatial domain into elements, in each of which the solution of the governing equations is approximated by continuous functions. The most promising FEM method is the improved dissipative Galerkin method (*Katopodes, 1984*).

4.2.2 Method of characteristics

Cunge (*1976*) presented a full treatise on the method of characteristics, and only a brief description will be given here.

The method utilises the fact that flow conforms with certain relationships along characteristic curves, therefore a solution can be evaluated along such characteristic curves. The partial differential equations are mathematically transformed into characteristic (ordinary differential) equations and solved on a grid.

The characteristic equations for the Saint Venant equations are as follows:

$$dv/dt + C\, dh/dt + g\,(S_f - S_o) = 0 \qquad (4.1)$$

$$dx/dt = V + C \qquad (4.2)$$

$dv/dt - C\,dh/dt + g(S_f - S_o) = 0$ .... (4.3)

$dx/dt = V - C$ ....(4.4)

where:

celerity $C = \sqrt{(gA/B)}$ ....(4.5)

Equations 4.1 and 4.2 are identified as the forward characteristic C+, whereas 4.3 and 4.4 as the backward characteristic C-.

Movement along characteristics lines represents possible wave motion across the water surface. The physical significance of a characteristic line is its gradient as it is an important feature of the theory. A small disturbance representing discontinuity in free water gradient dy/dx or velocity gradient dv/dt in an open channel propagates with celerity relative to the water.

Depending on the direction, three distinct states of water movement can be identified. For **subcritical** flow the celerity is greater than the absolute value of the flow velocity. The two characteristics therefore have opposite signs and the state at any point P is influence both from upstream and downstream conditions (Figure 4.1 a). For **critical** flow the celerity equals the absolute of flow velocity and one of the characteristic velocities of propagation becomes zero; that is the backward characteristic C- becomes a vertical line $x = x_p$ as shown in Figure 4.1 b. For **supercritical** flow the celerity is less than the absolute value of flow velocity and the two characteristics have the same sign (Figure 4.1 c and 4.1 d). In the latter two cases, the state at point P does not depend upon the downstream flow conditions.

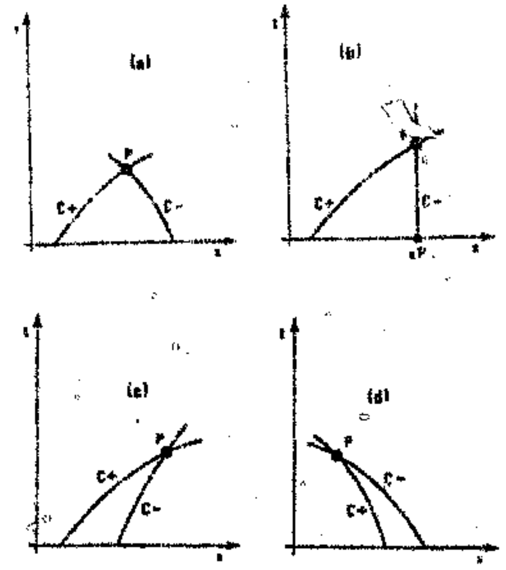

Figure 4.1 **Structure of the characteristics**
(Adapted from Cunge, et al, 1980)

4.2.3 Finite difference method

This method is based on representation of the continuously defined functions and its derivatives, in terms of approximate values defined at particular discreet points, called grid points. Thus the differential equations are replaced by algebraic finite difference relationships. The different ways in which derivatives and integrals are expressed by discreet functions are called finite difference schemes.

The computational grid (typically shown in Figure 4.2 below) is a finite set of points showing the same domain in the space-time plane as the continuous argument functions.

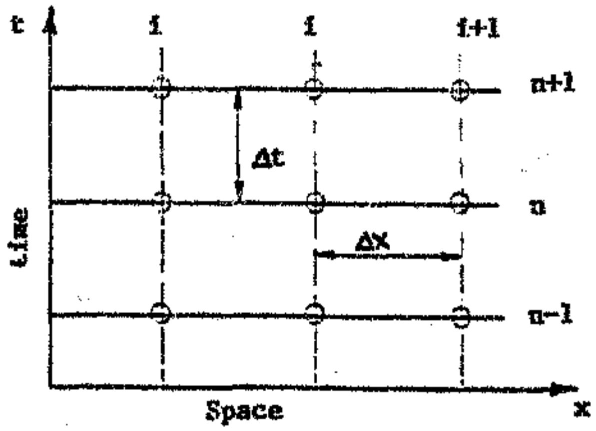

Figure 4.2 **Finite difference computational grid**

The differentiation of a continuous function F (x,t) can be approximated as:

$$\partial F/\partial x = \lim_{x \to 0} \{F(x + t, t) - F(x, t)\} / \Delta x \quad \ldots\ldots (4.1)$$

In finite difference, however, Δx is never infinitely small but represents a physical length of some importance.

The error introduced by replacing the differentials by finite difference is called **truncation error**. Cunge et al (*1980*) provided details regarding implication of this and thus is not included herein.

Furthermore this replacement implies that the numerical model must satisfy requirements of stability, accuracy and convergence. These are defined as follows (*Kolovopoulos, 1988*):

- **Stability:** "The ability of scheme to control the propagation or growth of a small disturbance introduced in the calculations".

- **Accuracy:** "The ratio of the difference between the approximate solution of the governing equations, divided by the exact solution".

- **Convergence:** "State of tending to a unique solution. A given scheme is convergent if an increasingly finer computational grid leads to a more accurate approximation of the unique solution. However, a numerical method may sometimes converge on the incorrect solution".

The convergence is governed by discretization errors. In practice, stability is a necessary condition for model operation since an unstable model is of little or no use.

Finite differences are divided into two categories; namely **explicit and implicit** schemes.

In **explicit schemes**, dependant variables at a rectangular grid point on the present time-line or present and previous time-lines on an advanced time-line are determined one point at a time, from known values and conditions at grid points.

For implicit schemes, a number of unknowns at the advanced time level are related to less-weighted known values at the current time level. Since there is more than one unknown in the finite difference equation, a full set of simultaneous equations must be solved.

4.4 Conclusions

a) *Finite element method*

The method has not found widespread application in mathematical modelling of river flow. As far as the problems are concerned, the method does not show any advantage over the other two and the legitimacy of its application to time dependant problems is not always clear cut (*Cunge et al, 1980*).

The majority of the schemes developed for the FEM use finite difference for the time derivatives. The advantage of the one-dimensional flow simulation appears doubtful to many Engineers. An additional constraint, is the extensive memory requirement of mounting the finite element model, within a suite of personal computer models. In view of the above reasons, a finite element model will not be considered in this study.

b) *Method of characteristics*

The method has the following advantages:

- Ease of implementation, partial differential equations yield to straight forward ordinary differential equations.

- The mathematics of the method underlines the essential physical wave behaviour. Characteristic directions are the time-space paths of information flow in the physical system.

- The method easily accommodates supercritical flows.

Despite these features, the method is criticised for two major shortcomings in implementation:

- In most characteristic based techniques the time-steps are limited by stability criteria that restrict the relationship between time and space-mesh parameters.

- The need for a common time-step during non-linear events and at element boundaries, necessitates the use of either interpolation or geometric adjustments, which introduce errors into the solution.

c) *Finite difference method*

In general, finite difference schemes are relatively easy to understand, formulate and program. However, these can be computationally inefficient due to numerical instability problems.

Ligget and Woolhiser (*1967*) however, found explicit schemes are accurate and economic when correctly used. Based primarily on stability rather than accuracy or efficiency requirements, explicit schemes are inflexible as they are limited for stability reasons to relatively small time steps. Further implicit schemes were found to be considerably stable for any choice of Δx and Δt. Due to large time steps required to route real time floods in natural rivers, implicit methods have been increasingly used. The methods do not, in general, have stability difficulties of the explicit methods or of the explicit characteristic method.

d) *Choice of method*

The finite difference scheme was chosen for this study noting:

- In river simulation problem, where long time-steps can be adopted, the implicit scheme is preferable (*Kolovopoulos, 1988*).
- Implicit schemes are considerably more stable for any choice of Δx and Δt.
- Most river modelling systems currently in use are based in implicit schemes.

CHAPTER 5

5.0 IMPLICIT ADVECTIVE WATER QUALITY MODEL

5.1 General

The most widely used implict finite difference scheme is the box scheme. The box scheme adopted for this study is the popular Preismann Scheme developed in France (*Preismann, 1961; Preismann and Cunge, 1961*).

In formulation of the model the procedure comprises the steps as set out and described in Figure 5.1 below:

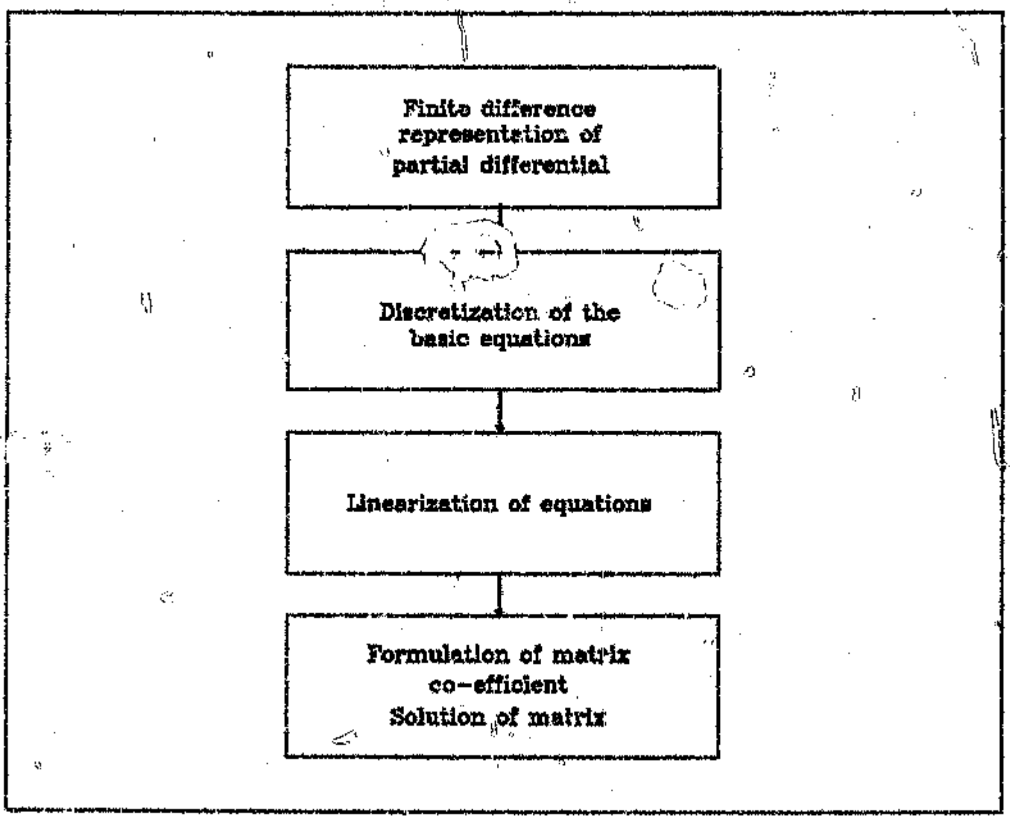

Figure 5.1 **Steps for formulation of model**

5.2 Finite difference representation

5.2.1 Discretization definitions

Considering a non-uniform rectangular grid on the space-time plane, as shown in Figure 5.2 below.

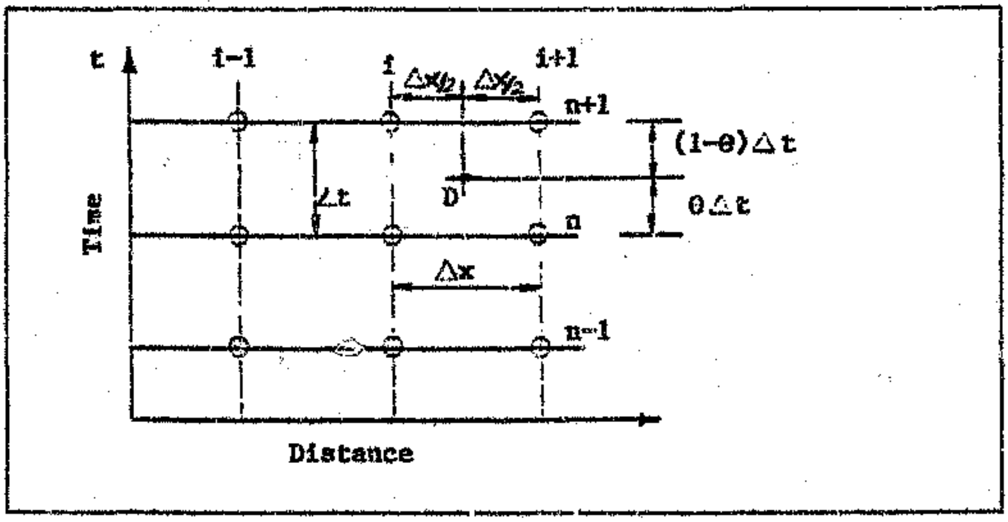

Figure 5.2 **Network of point on space-time plane**

For any variable h at point D the partial derivatives of function h are represented by:

$$\partial h/\partial x\,(D) = \theta\,[h_{i+1}^{n+1} - h_{i}^{n+1}]/\Delta x + (1-\theta)\,[h_{i+1}^{n} - h_{i}^{n}]/\Delta x \quad \text{.......................} (5.1)$$

$$\partial h/\partial x\,(D) = [h_{i+1}^{n+1} - h_{i+1}^{n}] + [h_{i}^{n+1} - h_{i}^{n}]/2\Delta t \quad \text{.......................} (5.2)$$

5.2.2 Application to hydrodynamic equations

a) *Continuity equation*

$$\partial Q/\partial x + B(z)\,\partial h/\partial t = 0 \quad \text{.......... (3.1)}$$

$$\theta\ \{Q_{i+1}^{n+1} - Q_i^{n+1}\}/\Delta x + (1-\theta)\ \{Q_{i+1}^{n} - Q_i^{n}\}/\Delta x\ +$$

$$B\ \{h_{i+1}^{n+1} - h_{i+1}^{n} + h_i^{n+1} - h_i^{n}\}/2\Delta t = 0 \quad \text{.......... (5.3)}$$

Simplifying and rearranging:

$$h_i^{n+1}\ \{B/2\Delta t\} + Q_i^{n+1}\ \{-\theta/\Delta x\} + h_{i+1}^{n+1}\ \{B/2\Delta t\} + Q_{i+1}^{n+1}\ \}\ \theta/\Delta x$$

$$+\ \{(1-\theta)\ (Q_{i+1}^{n} - Q_i^{n})/\Delta x - B\ (h_{i+1}^{n} + h_i^{n})/2\Delta t\} = 0 \quad \text{.......... (5.4)}$$

Multiplying by $2\Delta x\Delta t$

$$h_i^{n+1}\ \{B\Delta x\} + Q_i^{n+1}\ \{-2\theta\Delta t\} + h_{i+1}^{n+1}\ \{B\Delta x\} + Q_{i+1}^{n+1}\ \{2\theta\Delta t\}$$

$$+\ \{2(1-\theta)\ (Q_{i+1}^{n} - Q_i^{n})\Delta t - B\ (h_{i+1}^{n} + h_i^{n})\ \Delta x\} = 0 \quad \text{.......... (5.5)}$$

Let:

$$C_1 = B\Delta x \quad \text{.......... (5.5.1)}$$

$$C_2 = -2\theta\Delta t \quad \text{.......... (5.5.2)}$$

$$C_3 = B\Delta x \quad \text{.......... (5.5.3)}$$

$$C_4 = 2\theta\Delta t \quad \text{.......... (5.5.4)}$$

$$C_5 = -[2(1-\theta)\ (Q_{i+1}^{n} - Q_i^{n})\Delta t - B(h_{i+1}^{n} + h_i^{n})\Delta x] \quad \text{.......... (5.5.5)}$$

$$\therefore\ \{C_1\}\ h_i^{n+1} + \{C_2\}\ Q_i^{n+1} + \{C_3\}\ h_{i+1}^{n+1} + \{C_4\}\ Q_{i+1}^{n+1} = \{C_5\} \quad \text{.......... (5.6)}$$

b) *Momentum equation (Diffusion approximation)*

$$gA\frac{\partial h}{\partial x} + gA(S_f - S_o) = 0 \qquad \text{.......... (3.2.1)}$$

The term S_f was discretised as follows (*Cunge et al, 1980*):

$$gA\left\{\frac{\theta}{2}\left[\frac{Q_i^{n+1}|Q_i^n|}{(K_i)^2} + \frac{Q_{i+1}^{n+1}|Q_{i+1}^n|}{(K_{i+1})^2}\right] + \frac{(1-\theta)}{2}\left[\frac{Q_i^n|Q_i^n|}{(K_i^n)^2} + \frac{Q_{i+1}^n|Q_{i+1}^n|}{(K_{i+1}^n)^2}\right]\right\} \qquad \text{.......... (5.8)}$$

$$gA\left\{\frac{\theta(h_{i+1}^{n+1} - h_i^{n+1})}{\Delta x} + (1-\theta)\frac{(h_{i+1}^n - h_i^n)}{\Delta x} + gA(S_f - S_o)\right\} = 0 \qquad \text{..... (5.7)}$$

Simplyfying and rearranging

$$h_i^{n+1}\left\{\frac{-gA\theta}{\Delta x}\right\} + Q_i^{n+1}\left\{\frac{\theta}{2}gA\frac{|Q_i^n|}{(K_i)^2}\right\} + h_{i+1}^{n+1}\left\{\frac{gA\theta}{\Delta x}\right\} + Q_{i+1}^{n+1}\left\{\frac{\theta}{2}gA\frac{|Q_{i+1}^n|}{(K_{i+1})^2}\right\}$$

$$+ gA(1-\theta)\frac{(h_{i+1}^n - h_i^n)}{\Delta x} + [gA(1-\theta)/2]\left[\frac{Q_i^n|Q_i^n|}{(K_i^n)^2} + \frac{Q_{i+1}^n|Q_{i+1}^n|}{(K_{i+1}^n)^2}\right]$$

$$- gA S_o = 0 \qquad \text{.......... (5.9)}$$

Multiplying by $2\Delta x\Delta t$

$$h_i^{n+1}\{-2gA\theta\Delta t\} + Q_i^{n+1}\left\{gA\theta\frac{|Q_i^n|}{(K_i^n)^2}\Delta x\Delta t\right\} + h_{i+1}^{n+1}\{2gA\theta\Delta t\}$$

$$+ Q_{i+1}^{n+1}\left\{gA\theta\frac{|Q_{i+1}^n|}{(K_{i+1}^n)^2}\Delta x\Delta t\right\} + \{2gA(1-\theta)(h_{i+1}^n - h_i^n)\Delta t\}$$

$$+ \left\{gA(1-\theta)\left[Q_i^n\frac{|Q_i^n|}{(K_i^n)^2} + Q_{i+1}^n\frac{|Q_{i+1}^n|}{(K_{i+1}^n)^2}\right]\Delta x\Delta t\right\} - 2gA S_o\Delta x\Delta t = 0$$

$$\text{.......... (5.10)}$$

Let:

$$M_1 = \{-2gA\theta\Delta t\} \quad \text{.......... (5.10.1)}$$

$$M_2 = gA\,\theta \frac{|Q_i^n|}{(K_i^n)^2}\Delta x\Delta t\,\} \quad \text{.......... (5.10.2)}$$

$$M_3 = \{2gA\theta\Delta t\} \quad \text{.......... (5.10.3)}$$

$$M_4 = gA\,\theta \frac{|Q_{i+1}^n|}{(K_{i+1}^n)^2}\Delta x\Delta t \quad \text{.......... (5.10.4)}$$

$$F_1 = 2gA\,(1-\theta)\,(h_{i+1}^n - h_i^n)\,\Delta t \quad \text{.......... (5.10.5)}$$

$$F_2 = \{\, gA\,(1-\theta)\;\; Q_i^n \frac{|Q_i^n|}{(K_i^n)^2} \;\; \Delta x\Delta t\,\} \quad \text{.......... (5.10.6)}$$

$$F_3 = \{\, gA\,(1-\theta)\;\; Q_{i+1}^n \frac{|Q_{i+1}^n|}{(K_{i+1}^n)^2} \;\; \Delta x\Delta t\,\} \quad \text{.......... (5.10.7)}$$

$$F_4 = -2gA\,S_o\,\Delta x\Delta t \quad \text{.......... (5.10.8)}$$

$$M_5 = -\{F_1 + F_2 + F_3 + F_4\} \quad \text{.......... (5.10.9)}$$

$$\therefore \quad \{M_1\}\,h_i^{n+1} + \{M_2\}\,Q_i^{n+1} + \{M_3\}\,h_{i+1}^{n+1} + \{M_4\}\,Q_{i+1}^{n+1} = \{M_5\} \quad \text{..... (5.11)}$$

5.2.3 Application to pollutant transport equations

a) *Mass-balance equation*

$$\frac{\partial C}{\partial t} + K_p C + \frac{C}{A}\frac{\partial Q}{\partial x} + v\frac{\partial C}{\partial x} = 0 \quad \text{.......... (3.6.1)}$$

$$\frac{C_{i+1}^{n+1} - C_{i+1}^{n}}{2\Delta t} + \frac{C_i^{n+1} - C_i^{n}}{2\Delta t} + K_p C + \frac{C}{A}\quad \theta\frac{(Q_{i+1}^{n+1} - Q_i^{n+1})}{\Delta x} +$$

$$(1-\theta)\frac{(Q_{i+1}^{n} - Q_i^{n})}{\Delta x} + v \quad \theta\frac{(C_{i+1}^{n+1} - C_i^{n+1})}{\Delta x} + (1-\theta)\frac{(C_{i+1}^{n} - C_i^{n})}{\Delta x} = 0$$

$$\text{.......... (5.12)}$$

Simplifying and rearranging

$$C_i^{n+1}\left\{\frac{1}{2\Delta t}-\frac{\theta V}{\Delta x}\right\}+C_{i+1}^{n+1}\left\{\frac{1}{2\Delta t}+\frac{V\theta}{\Delta x}\right\}+K_pC-\frac{1}{2\Delta t}(C_{i+1}^{n}+C_i^{n})$$

$$\frac{(C)}{A}\ \theta\frac{(Q_{i+1}^{n+1}-Q_i^{n+1})}{\Delta x}+(1-\theta)\frac{(Q_{i+1}^{n}-Q_i^{n})}{\Delta x}+V(1-\theta)\frac{(C_{i+1}^{n}-C_i^{n})}{\Delta x}=0$$

.... (5.13)

Multiplying by $2\Delta x\Delta t$

$$C_i^{n+1}\{\Delta x-2\theta V\Delta t\}+C_{i+1}^{n+1}\{\Delta x+2\theta V\Delta t\}+2K_p\,C\,\Delta x\Delta t-(C_i^n+C_i^n)\Delta x$$

$$+\frac{2C}{A}\{\theta(Q_{i+1}^{n+1}-Q_i^{n+1})+(1-\theta)(Q_{i+1}^{n}-Q_i^{n})\}\Delta t+2V(1-\theta)(C_{i+1}^{n}-C_i^{n})\Delta t=0$$

.... (5.14)

Let:

$P_1 = \{\Delta x - 2\theta V\Delta t\}$ .... (5.14.1)

$P_2 = \{\Delta x + 2\theta V\Delta t\}$ .... (5.14.2)

$P_{3A} = \{2K_pC\,\Delta x\Delta t - (C^n + C^n)\,\Delta x\}$ .... (5.14.3)

$P_{3B} = \{\frac{2C}{A}[\theta(Q_{i+1}^{n+1} - Q_i^{n+1})\,\Delta t]\}$ .... (5.14.4)

$P_{3C} = \{\frac{2C}{A}[1-\theta)(Q_{i+1}^{n} - Q_i^{n})]\,\Delta t\}$ .... (5.14.5)

$P_{3D} = \{2V(1-\theta)(C_{i+1}^{n} - C_i^{n})\,\Delta t\}$ .... (5.14.6)

$P_3 = -(P_{3A} + P_{3B} + P_{3C} + P_{3D})$ .... (5.14.7)

$\therefore \quad \{P_1\}\ C_i^{n+1} + \{P_2\}\ C_{i+1}^{n+1} = \{P_3\}$ .... (5.15)

5.2.4 Linearization of discretized equations

The resulting equations (5.6, 5.11 and 5.15) are non-linear, due to dependance of the co-efficients such as A(z), B(z) and K(z) on the flow variable. Verwey in his

Preismann formulation (*Cunge et al, 1980*), represented the co-efficients of flow as follows:

$$F = (F_i^n + F_{i+1}^n) / 2 \quad \text{.......} \quad (5.16)$$

for first iterations

$$F = \theta \, [F_{i+1}^{n+1/2} + F_{i+1}^{n+1/2}] / 2 + (1 - \theta) \, [F_{i+1}^n + F_i^n] \quad \text{.......} \quad (5.17)$$

for any subsequent iterations

where:

F may represent A(z), B(z) or K(z). The superscript (n + ½) shows that the function is evaluated within time step.

Similarly:

A_i, K_i and Q_i are set as:

$$F_i = F_i^n \quad \text{.......} \quad (5.18)$$

for first iterations

$$F_i = \theta \, F_i^{n+1/2} + (1 - \theta) \, F_i^n \quad \text{.......} \quad (5.19)$$

for any subsequent iterations

Although the equations are not fully linearised, calculations for each iteration within a time-step, makes it possible to solve the set of algebraic equations as linear systems.

Preismann formulation (*Cunge et al, 1980*), represented the co-efficients of flow as follows:

$$F = (F_i^n + F_{i+1}^n) / 2 \quad \text{.......} \quad (5.16)$$

for first iterations

$$F = \theta \, [F_{i+1}^{n+½} + F_{i+1}^{n+½}] / 2 + (1 - \theta) \, [F_{i+1}^n + F_i^n] \quad \text{.......} \quad (5.17)$$

for any subsequent iterations

where:

F may represent A(z), B(z) or K(z). The superscript (n + ½) shows that the function is evaluated within time step.

Similarly:

A_i, K_i and Q_i are set as:

$$F_i = F_i^n \quad \text{.......} \quad (5.18)$$

for first iterations

$$F_i = \theta \, F_i^{n+½} + (1 - \theta) \, F_i^n \quad \text{.......} \quad (5.19)$$

for any subsequent iterations

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Preismann formulation (*Cunge et al, 1980*), represented the co-efficients of flow as follows:

$$F = (F_i^n + F_{i+1}^n) / 2 \quad \text{.......} (5.16)$$

for first iterations

$$F = \theta [F_{i+1}^{n+½} + F_{i+1}] / 2 + (1 - \theta) [F_{i+1}^n + F_i^n] \quad \text{.......} (5.17)$$

for any subsequent iterations

where:

F may represent A(z), B(z) or K(z). The superscript (n + ½) shows that the function is evaluated within time step.

Similarly:

A_i, K_i and Q_i are set as:

$$F_i = F_i^n \quad \text{.......} (5.18)$$

for first iterations

$$F_i = \theta F_i^{n+½} + (1 - \theta) F_i^n \quad \text{.......} (5.19)$$

for any subsequent iterations

Although the equations are not fully linearised, calculations for each iteration within a time-step, makes it possible to solve the set of algebraic equ . as linear systems.

5.3 Boundary Conditions

An implicit scheme requires two boundary conditions, upstream and downstream to furnish a solution. The boundary conditions for the hydrodynamic sub-model can comprise of any one set of the following known quantities:

- upstream and downstream stage hydrographs
- upstream and downstream flow hydrographs
- upstream stage hydrograph and downstream flow hydrograph
- upstream flow hydrograph and downstream stage hydrograph
- upstream stage hydrograph and downstream rating curve
- upstream flow hydrograph and downstream rating curve

In steady state conditions the most convenient boundary condition to apply downstream is the water stage hydrograph, whereas for steady state, a single value flow would be appropriate. However during model exploitation runs, the water stage hydrograph downstream will not generally be available unless the downstream limit is a reservoir or tidal condition.

For pollutant transport the initial spatial distribution of pollutant concentration C(t) upstream is the only possible boundary condition.

5.4 Formulation of solution matrix

The formulation of the solution matrix can be demonstrated by an example with five cross-sections. The four reaches result in eight equations, it follows that (n - 1) reaches would result in 2(n - 1) equations. The example is as follows:

a) *Hydrodynamics*

Reach 1 : $C_1h(1) + C_2Q(1) + C_3h(2) + C_4Q(2) = C_5$ .... (5.20a)
$M_1h(1) + M_2Q(1) + M_3h(2) + M_4Q(2) = M_5$ .... (5.20b)

Reach 2 : $C_1h(2) + C_2Q(2) + C_3h(3) + C_4Q(3) = C_5$ .... (5.20c)
$M_1h(2) + M_2Q(2) + M_3h(3) + M_4Q(3) = M_5$ .... (5.20d)

Reach 3 : $C_1h(3) + C_2Q(3) + C_3h(4) + C_4Q(4) = C_5$ .... (5.20e)
$M_1h(3) + M_2Q(3) + M_3h(4) + M_4Q(4) = M_5$ .... (5.20f)

Reach 4 : $C_1h(4) + C_2Q(4) + C_3h(5) + C_4Q(5) = C_5$ .... (5.20g)
$M_1h(4) + M_2Q(4) + M_3h(5) + M_4Q(5) = M_5$ .... (5.20h)

Boundary conditions : Known upstream flow hydrograph and downstream stage hydrograph.

Equations 5.20a, 5.20b, 5.20g, and 5.20h become:

$C_1h(1) + C_3h(2) + C_4Q(2) = C_5 - C_2Q(1) = C_5^*$ .... (5.21a)
$M_1h(1) + M_3h(2) + M_4Q(2) = M_5 - M_2Q(1) = M_5^*$ .... (5.21b)

$C_1h(4) + C_2Q(4) + C_4Q(5) = C_5 - C_3h(5) = C_5^*$ .... (5.21c)
$M_1h(4) + M_2Q(4) + M_4Q(5) = M_5 - M_3h(5) = M_5^*$ .... (5.21d)

The resulting solution matrix is as follows:

$$\begin{bmatrix} C_1 & C_3 & C_4 & 0 & 0 & 0 & 0 & 0 \\ M_1 & M_3 & M_4 & 0 & 0 & 0 & 0 & 0 \\ 0 & C_1 & C_2 & C_3 & C_4 & 0 & 0 & 0 \\ 0 & M_1 & M_2 & M_3 & M_4 & 0 & 0 & 0 \\ 0 & 0 & 0 & C_1 & C_2 & C_3 & C_4 & 0 \\ 0 & 0 & 0 & M_1 & M_2 & M_3 & M_4 & 0 \\ 0 & 0 & 0 & 0 & 0 & C_1 & C_2 & C_4 \\ 0 & 0 & 0 & 0 & 0 & M_1 & M_2 & M_4 \end{bmatrix} \quad X \quad \begin{bmatrix} h(1) \\ h(2) \\ Q(2) \\ h(3) \\ Q(3) \\ h(4) \\ Q(4) \\ Q(5) \end{bmatrix} = \begin{bmatrix} C_5^* \\ M_5^* \\ C_5 \\ M_5 \\ C_5 \\ M_5 \\ C_5^* \\ M_5^* \end{bmatrix}$$

The matrix is banded and pentagiagonal i.e. all its non-zeros lie in a relatively narrow region about the main diagonal, and the band width is derived from the maximum number of non-zero entries to any one side of the diagonal. If this number is m the band width = 2m + 1.

b) *Pollutant tranport*

Applying similar procedures and examples as for (a):

Reach 1 : $P_1C(1) + P_2C(1) = P_3$ .... (5.22a)

Reach 2 : $P_1C(2) + P_2C(3) = P_3$ .... (5.22b)

Reach 3 : $P_1C(3) + P_2C(4) = P_3$ .... (5.22c)

Reach 4 : $P_1C(4) + P_2C(5) = P_3$ .... (5.22d)

Boundary conditions : known upstream pollutant concentration

Equation 5.22a thus, becomes:

$$(P_2)\,C(2) = P_3 - (P_1)\,C(1) = P_3^* \qquad (5.23)$$

The matrix solution is as shown:

$$\begin{bmatrix} P_2 & 0 & 0 & 0 \\ P_1 & P_2 & 0 & 0 \\ 0 & P_1 & P_2 & 0 \\ 0 & 0 & P_1 & P_2 \end{bmatrix} \times \begin{bmatrix} C(2) \\ C(3) \\ C(4) \\ C(5) \end{bmatrix} = \begin{bmatrix} P_3^* \\ P_3 \\ P_3 \\ P_3 \end{bmatrix}$$

The resulting matrix is also banded.

5.5 Solution algorithm for the model

The solution of the linearised matrix may be obtained using any available methods for solving simultatneous equations. The most important equations are Gauss elimination, Gauss-Siedel, and the Double-Sweep method.

Sternberg (*1989*) and Kolovopolous (*1988*) presented a concise summary of the methods and the **Double-Sweep** approach was found to be the most efficient. This method is the most frequently used in industrial modelling (*Cunge et al, 1980*) and the principle of the sweep algorithm was used in this study. It uses a banded matrix structure of the linear system of equations to compute the solution.

$$\begin{bmatrix} c_1 & d_1 & e_1 & & & & & \\ b_2 & c_2 & d_2 & e_2 & & & & \\ a_3 & b_3 & c_3 & d_3 & & & & \\ & a_4 & b_4 & c_4 & d_4 & e_4 & & \\ & & a_5 & b_5 & c_5 & d_5 & e_5 & \\ & & & & a_{n-1} & b_{n-1} & c_{n-1} & d_{n-1} \\ & & & & & a_n & b_n & c_n \end{bmatrix} \quad X \quad \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_{n-1} \\ X_n \end{bmatrix} = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_{n-1} \\ f_n \end{bmatrix}$$

The algorithm for this system as derived by Wilkinson and Reinsch (*1971*), Meis and Markowitz (*1981*), is as follows:

$Pd_1 = d_1/c_1$
$Pl_1 = e_1/c_1$
$Pg_1 = f_1/c_1$
$Pm_2 = c_2 - b_2 * Pd_1$

$Pd_2 = (d_2 - b_2\, Pd_1)/Pm_2$
$Pl_2 = e_2/Pm_2$
$Pg_2 = (f_2 - b_2\, Pg_1)Pm_2$

$Pb_i = b_i - a_i * Pd_{i-2}$
$Pm_i = c_i - Pb_i * Pd_{i-1} - a_i * Pl_{i-2}$ for $i = 3,4 \ldots, (n-2)$
$Pd_i = (d_i - Pb_i * Pl_{i-1})/Pm_i$

$$Pl_i = e_i/Pm_i$$
$$Pg_i = (f_i - Pb_i * Pg_{i-1} - a_i * Pg_{i-2})/Pm_i$$

$$Pb_{n-1} = b_{n-1} - a_{n-1} Pd_{n-3}$$
$$Pm_{n-1} = c_{n-1} - Pb_{n-1} * Pd_{n-2} - a_{n-1} Pl_{n-3}$$
$$Pd_{n-1} = (d_{n-1} - Pb_{n-1} * Pl_{n-2})/Pm_{n-1}$$
$$Pg_{n-1} = (f_{n-1} - Pb_{n-1} * Pg_{n-2} - a_{n-1} Pg_{n-3})/Pm_{n-1}$$
$$Pb_n = b_n - a_n Pd_{n-2}$$
$$Pm_n = c_n - Pb_n * Pd_{n-1} - a_n Pl_{n-2}$$
$$Pg_n = (f_n - Pb_n * Pg_{n-1} - a_n Pg_{n-2})/Pm_n$$

$$X_n = Pg_n$$
$$X_{n-1} = Pg_{n-1} - Pd_{n-1} X_n$$

$$X_i = Pg_i - Pd_i * X_{i+1} - Pl_i * X_{i+2} \} \qquad i = n - 2, n - 3 ..., 2.1.$$

The efficiency of the algorithm lies in the speed and minimum storage requirements through realising that the arrays Pb_i and Pm_i are only used to compute the array Pd_i, Pl_i and Pg_i and need not be stored once the latter groups have been evaluated.

CHAPTER 6

6.0 STRUCTURE OF THE ADVECTIVE WATER QUALITY MODEL

6.1 General

To sustain the pre-development aims which were as set out in the introductory chapter, a suite of computer programs were developed. The suite was designated **WATQUA** (Advective Water Quality model), Version 1.0, September 1991.

WATQUA was compiled by Microsoft **QUICKBASIC**, compiler for IBM Personal Computers and compatibles.

The model comprises of four modules, namely: Driving module, Input handling, Main computation and Output handling. Figure 6.1 indicates a brief description of the model structure.

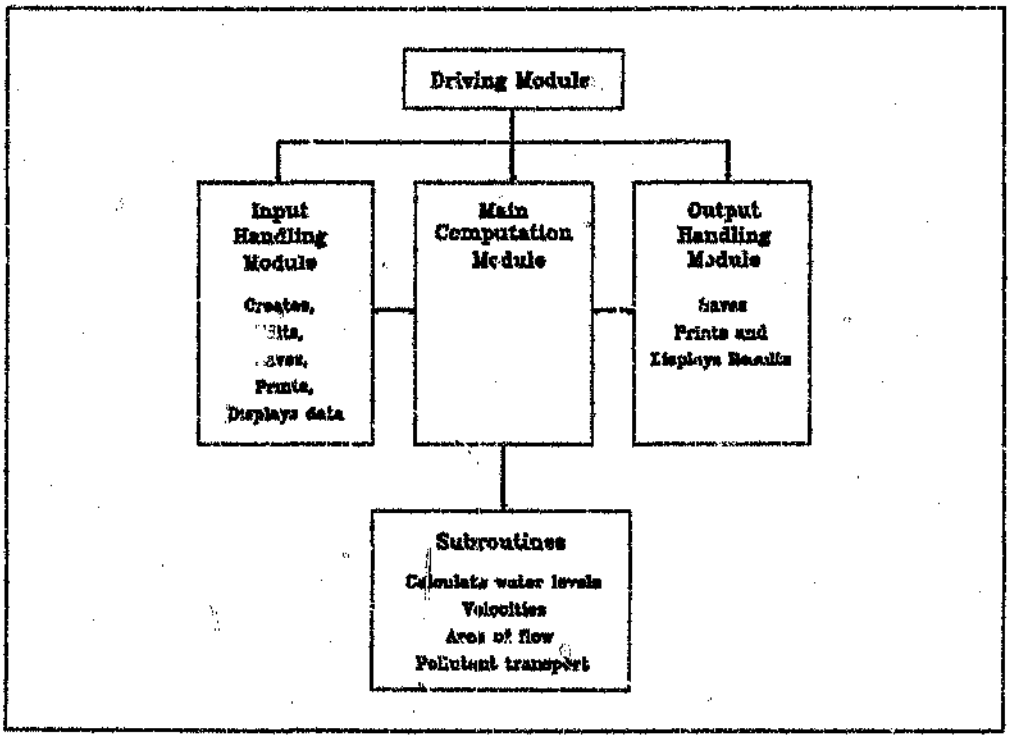


Figure 6.1 **WATQUA model structure**

6.1.1 Input handling

WATQUA is supported by a flexible input handling menu driven module. The module enables the user to create a new file, input, edit, view and print data.

Input includes cross-sectional and boundary conditions data which are stored in separate files. The model accepts up to 90 cross-sections of any geometry with 10 (elevation, station) pairs. Boundary condition data comprises pollutographs, hydrograph, etc, with maximum number of ordinates equal to 90. The set up provides greater flexibility as the same cross-sectional data files can be combined with different boundary files.

6.1.2 Computation

The model initially assumes steady state conditions and uses the results thereof to initialise variables. The calculation involves evaluation of matrix co-efficients and solution of the banded matrix for various time steps. The computations are undertaken in two stages:

- hydrodynamic portion
- pollutant transport portion, which uses results evaluated from the hydrodynamic model.

Figure 6.2 overleaf depicts the computation algorithm.

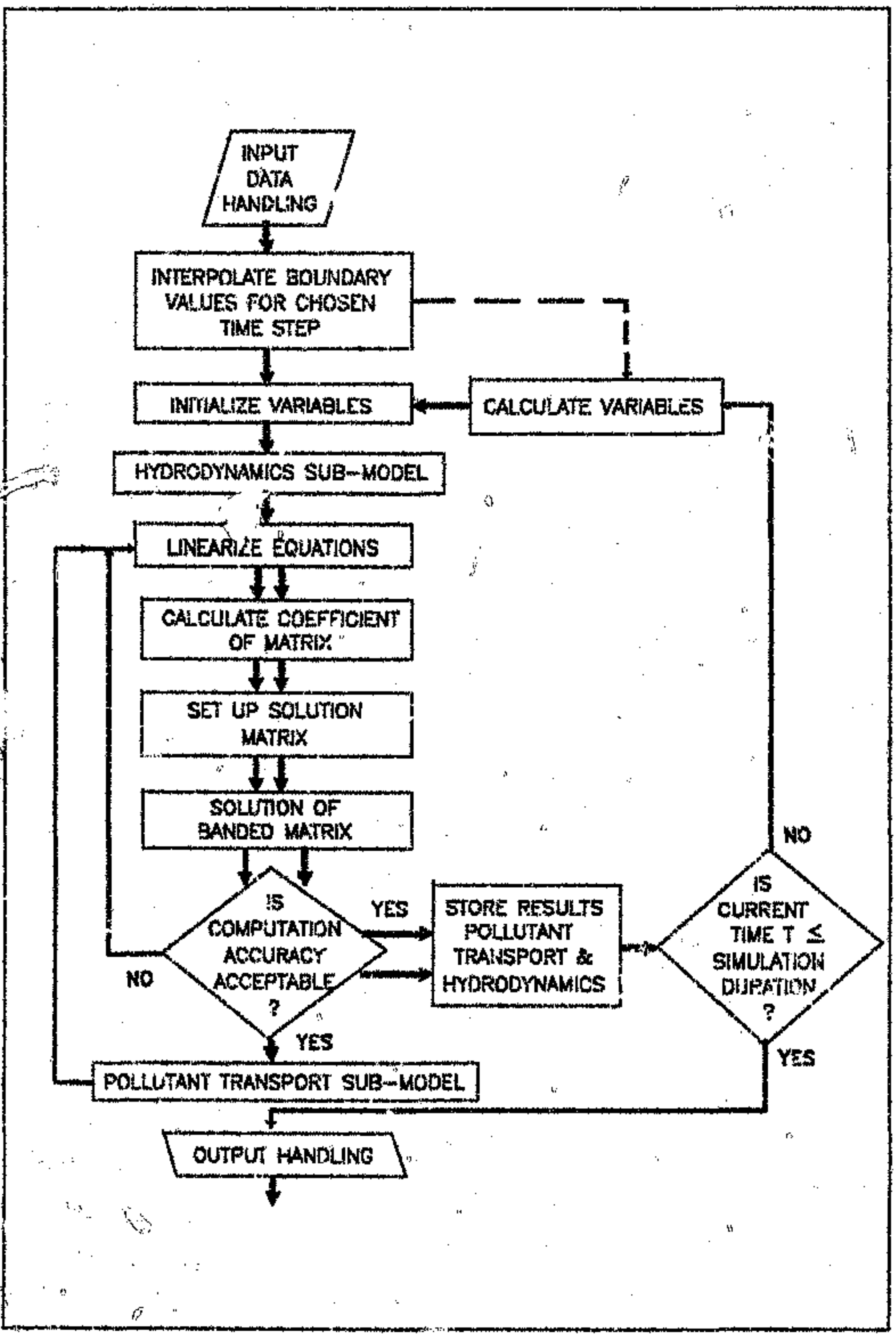


Figure 6.2 : **WATQUA computation algorithm**

6.1.3 Output handling

As a part of an operational system, a flexible output handling facility has been developed. The output handling facility enables results to be saved into a file, viewed on screen and even printed.

The model produces results such as water levels, velocity of flow, water quantity and quality distribution in time for a downstream station.

CHAPTER 7

7.0 MODEL APPLICATION

7.1 General

In representing real-life flow influences by mathematical abstraction, some degree of inaccuracy is inevitable. The extreme complexity of natural hydrological - hydraulic systems dictates some level of simplification in modelling. Some natural processes may not be described in detail whereas others may be completely excluded (*Schaake, 1972*).

The model presented here is "deterministic", that is, a model whose theoretical structure is based on the physical laws of nature. Consequ[illegible]y, with the correct choice of input, reliable output is expected. However, for reasons already highlighted, simplifying assumptions were made, henceforth an assessment with regard to its accuracy, validity and reliability is necessary.

Model calibration and verification is the key to model credibility. The extent to which the model output enters into and influences the decision making process and enhances the quality of those decisions, is dependent on its credibility. That credibility is, in turn, largely determined by the thoroughness of calibration and verification efforts and effectiveness of the means used to display and communicate the results.

Extensive data is required to adequately calibrate or verify a transport model. Whilst it is possible to assess such things as conservation of mass and stability using hypothetical parameters, it is however impossible to determine whether the basic physics are complete to represent the natural situation.

7.2 Methodology

Model calibration and verification involves rational adjustment of parameters within their acceptable limits to achieve the best fit between the natural event and model output.

To expedite the calibration process a variety of techniques are available. An overview of some of the techniques currently in use was presented by Walesh et al (*1978*). Johnston et al (*1976*) classified calibration techniques into two distinct categories. In the first category initial values of parameters are estimated from available information of the processes involved in what thereafter becomes an iterative process. The second category utilises mathematical optimization techniques to obtain optimum parameter values.

To exploit the interactive interphase of the proposed model, parameter adjustment to obtain optimum values was performed by utilizing an "educated" trial and error procedure. The procedure generally involves manipulation of weighting factor, such as θ, the time step to reach length ($\Delta t/\theta x$) ratio and channel conveyance factor.

A whole family of finite difference schemes may be obtained from equations 5.1 and 5.2 by varying the parameter θ. These range from fully implicit schemes when $\theta = 1$ to fully explicit schemes when $\theta = 0$. The selection of the appropriate values for θ is largely dependant on ' \rticular flow condition being simulated. For an unconditionally stable scheme, θ must lie in the range $0.5 < \theta \leq 1.0$. Implicit schemes are unconditionally stable for any $\Delta t/\Delta x$ ratio, henceforth its choice is not critical. However gross instability and inaccuracies could be incurred should this parameter be chosen erratically.

To assess the goodness of fit between computed results and observed data, two methods, that is graphical and statistical comparison, were used.

Graphical comparison present a quick and effective means of qualitatively assessing the competence of the model, whereas quantitative assessment is easily illustrated by statistical comparison. Various statistics were applied in assessment of the model, namely, sum of squared residuals (SSR), sum of absolute residuals (SAR), coefficient of efficiency (E) and correlation coefficient (RS_0). A concise brief and formulae of these statistics was presented by Kolovopoulos (*1988*) and henceforth will not be repeated here.

7.3 Model Calibration And Verification

Taking into cognisance the data requirements for the complete water quality model (joint hydrodynamics and pollutant transport), calibration and verification was undertaken in two stages. Stage 1 examined the competence of the hydrodynamic sub-model to route floods in an open channel and Stage 2 the ability of the complete model to represent the natural situation.

7.3.1 Assessment of hydrodynamic sub-model

The hydrodynamic sub-model was assessed with the aid of hypothetical data used by Tingsanchali and Manandhar (*1985*) to test their analytical diffusion model. The watercourse was characterized by a rectangular channel width = 100m, bed slope (S_o) = 1/10 000, reach length (L) = 60km, Manning's roughness coefficient (n) = 0.05 (equivalent Chezy roughness coefficient C = 25m½/s) and an initial uniform depth of 3m. A set of boundary conditions available were upstream and downstream stage hydrographs as indicated in Figure 7.1 below.

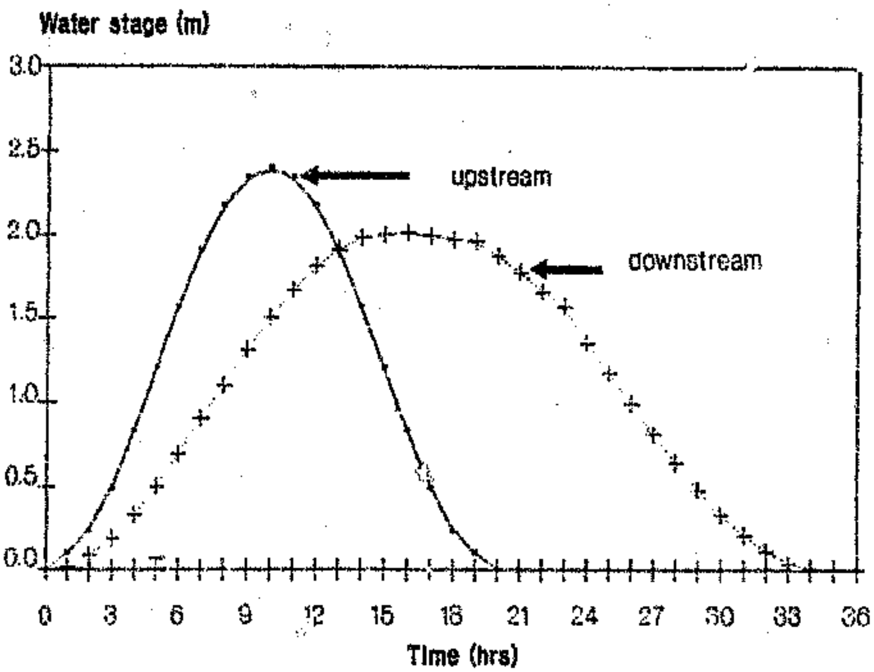


Figure 7.1 **Upstream and downstream stage hydrographs for hypothetical study**

An independent variation of parameters θ, Δt and Δx, culminating in eight model runs indicated in Table 7.1 below, was undertaken under the same boundary conditions.

A comparison between peak stage (above initial uniform flow depth) predicted by the proposed model and "observed" data was carried out. For convenience the results of the implicit finite difference scheme based on the complete Saint Venant equation at a station 48km from upstream limit was considered to be equivalent to observed data. The observed peak stage hydrograph is henceforth equal to 1.90m above the initial uniform flow depth (3m). Summary of the range of parameters and results are indicated in Table 7.1 below.

Table 7.1 **Range of parameters and results for hypothetical study**

Run number	θ	Δt (min)	Δx (m)	Computed peak stage (m)	% Change from observed stage
1	0.2	60	60	*	*
2	0.4	60	6000	*	*
3	0.6	60	6000	1.81	- 4.7
4	1.0	60	1000	1.82	- 4.2
5	0.6	30	6000	1.85	- 2.6
6	0.6	120	6000	1.78	- 6.3
7	0.6	60	1000	1.88	- 1.1
8	0.6	60	12000	2.10	+ 10.5

* *Unable to find results due to termination of program computation*

In addition to the above comparison statistical analysis and graphical comparison (Table 7.2) were also undertaken for the run number 7, which represent the best fit of peak stage at the same station. The parameters for this run correspond to those used by Tingsanchali and Manandhar (*1985*).

Table 7.2 **Summary of statistical analysis for hypothetical study**

Statistic		Value
Mean of stages (computed)	(m)	2.04
Means of stages (observed)	(m)	2.10
Ratio of means (computed/observed)		0.97
Mean of residuals	(m)	0.05
Sum of squared residuals	(m^2)	0.12
Sum of absolute residuals	(m)	1.14
Coefficient of efficiency		0.99
Correlation Coefficient		1.0

The graphical comparison of simulated and observed stage hydrographs is indicated in Figure 7.2 below.

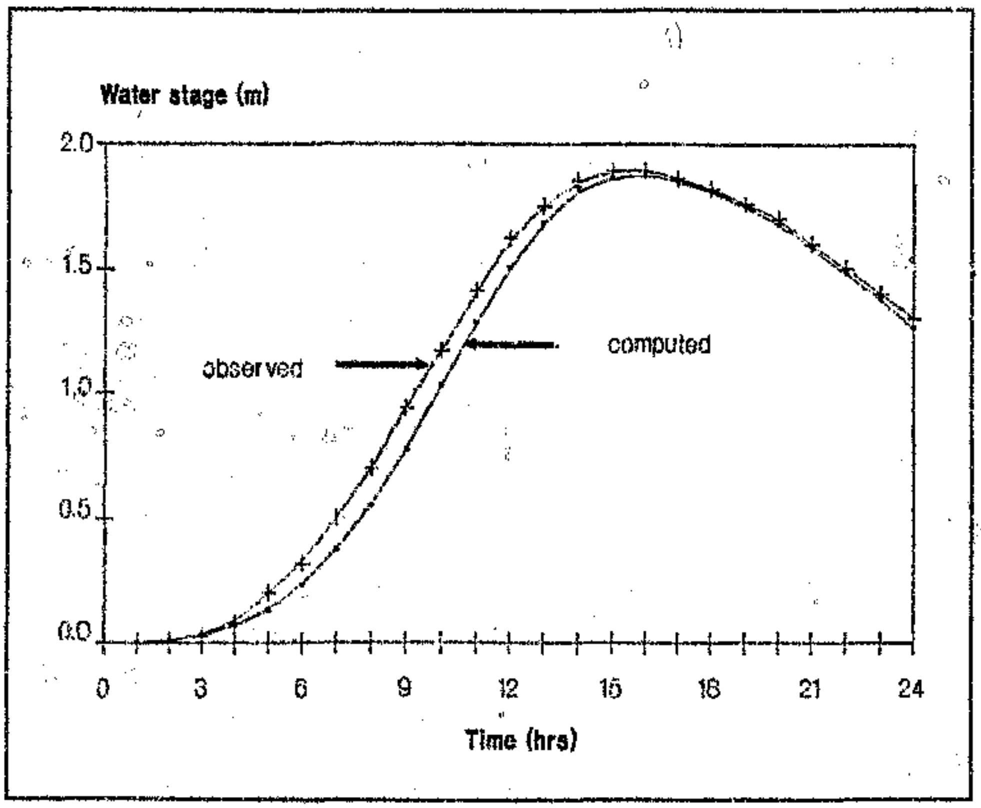


Figure 7.2 **Comparison of computed and observed stage hydrographs for hypothetical study**

On inspecting Tables 7.1, 7.2, Figures 7.2 and 7.3 the following conclusions were drawn:

- Due to termination of program computation for values of $\theta < 0.5$ no results were obtained (Runs 1 and 2 in Table 7.1).

- For $\theta = 0.6$ variation in computed peak stage from the "observed" peak stage is only -1.1% whereas for $\theta = 1.0$ is -4.2% (Runs 3 and 6 in Table 7.1). The most accurate results with regards peak stage were obtained when $\theta = 0.6$ (Run 7).

- Changes is $\Delta t/\Delta x$ ratio, likewise, did not significantly influence the stability not the accuracy (Runs 2 and 4 in Table 7.1).

- The coefficients used for statistical analysis are very close to unity and correlation is excellent (Table 7.2).

- Computed and observed stage hydrographs were found to be in perfect agreement (Figure 7.2).

7.3.2 Assessment of the complete water quality model

The ability of the complete model to conserve pollutant mass during advection was tested on observed data obtained from a portion of the Klip river. The Pretoria-

Witwatersrand-Vereeniging (PWV) complex, where the Klip river lies, constitutes the largest and most highly developed concentration of human activity in Southern Africa. This river henceforth represents a typical urban watercourse in the region.

The river rises in the vicinity of Roodepoort and then flows due south up to the vicinity of Lenasia where it flows east for a distance and then south again until it eventually drains into the Vaal river. Arnold (*1980*) undertook an extensive survey (river characteristics, flow rates, velocity and pollutant distribution) of a portion of the river stretching approximately 5.8km as indicated in Figure 7.3.

To suit the model the results of abovementioned survey were manipulated and adjusted accordingly. The river channel was represented by trapezoidal sections, bottom width = 10m, side slope (vertical : horizontal) = 1:3 equally spaced 540km apart.

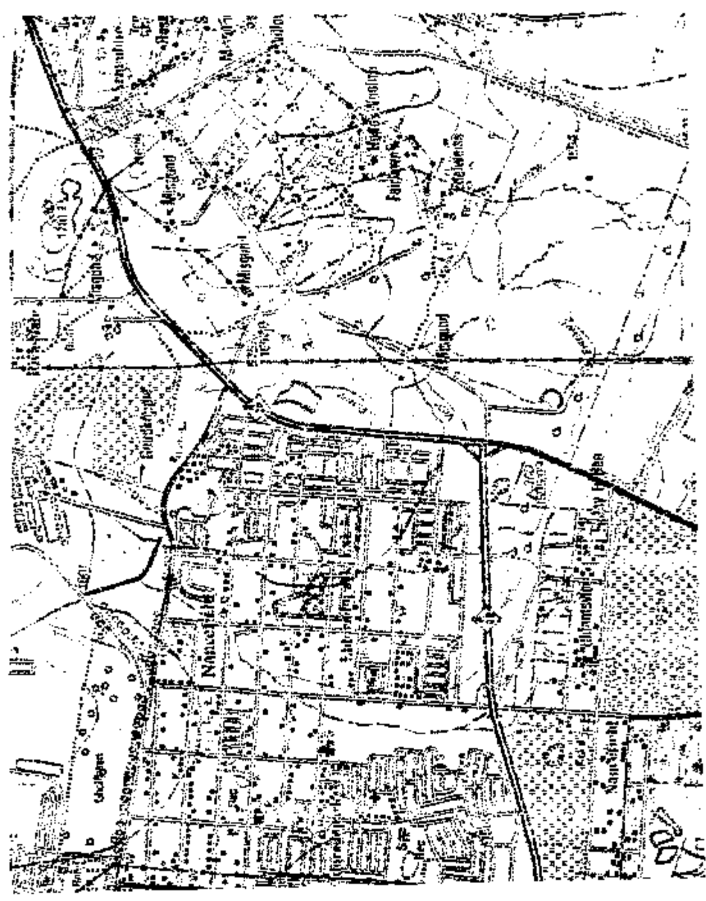
Flow and pollutant distribution data was available for two periods :

- First event : July 18, 1978
- Second event : March 21, 1979

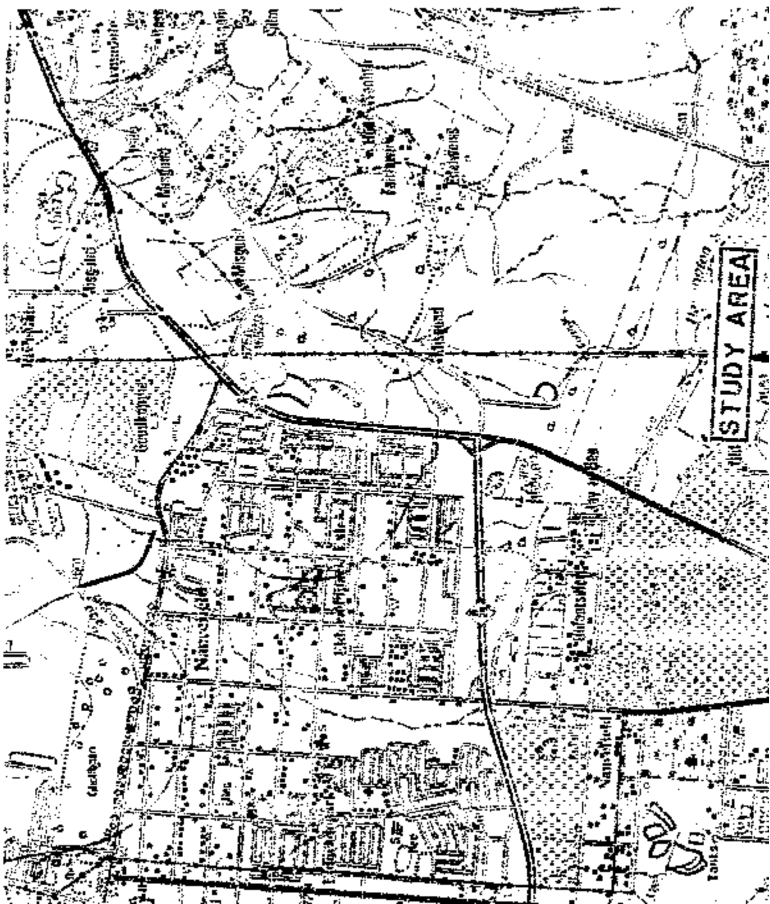
For the first event the average flow rate and velocities were approximated at 4.2 m^3/s and 0.33m/s respectively whereas for the second event at 3.4m^3/s and 0.23m/s respectively in each case for the entire reach over the complete sampling period.

Figure 7.3 **The Klip river study reach**

Chapter 7



Chapter 7



A high portion of flow in the Klip river originates from the industrial and mining areas as well as a number of sewage works. These flows coupled with the natural and urban runoff, results in high Total Dissolved Solids (TDS) load (*Herold, 1980*). On this basis TDS was chosen as a representative water quality indicator. Values of Conductivity obtained by Arnold (*1980*) were converted to TDS at 25°C with the aid of the following relationships as presented by Green et al (*1986*):

$$C_{t1} = C_{t2} \ (1 + 0.008 \ (t_2 - t_1)) \qquad (7.1)$$

where

C_{t1} is the conductivity at temperature t_1

C_{t2} is the conductivity at temperature t_2

$$TDS = (19.59 + 7.22 \ C_{t1}) \qquad (7.2)$$

The following were adopted as the boundary conditions:

- upstream flow rate
- downstream flow rate
- upstream TDS pollutograph (Figures 7.4 and 7.5)

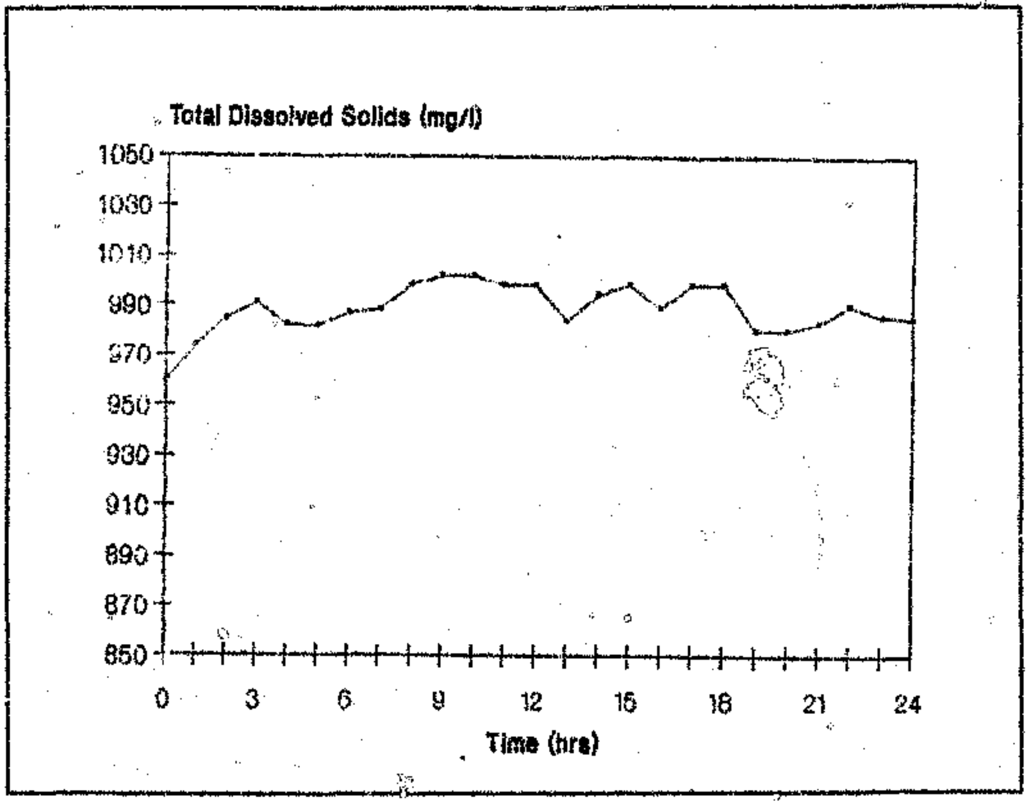


Figure 7.4 **Upstream inflow TDS pollutograph for the Klip river July 18, 1978**

Several runs were performed using data of the first event to obtain an optimum value of channel roughness corresponding to given flow rate and velocity. The values of θ and Δt were chosen to be 0.6 and 60 minutes respectively.

The computed downstream pollutograph was compared to the observed pollutographs. The success of the simulation was evaluated from statistics in Table 7.3 and from graphical aid in Figure 7.5.

Table 7.3 **Summary of statistical analysis for the Klip river July 18, 1978**

Statistic	Value
Mean of observed TDS (mg/l)	1235.92
Mean of computed TDS (mg/l)	1234.51
Ratio means (computed/observed)	0.99
Mean of residuals (mg/l)	14.158
Sum of squared residuals (mg^2/l^2)	7105.75
Sum of absolute residuals (mg/l)	353.96
Coefficient of efficiency	- 0.16
Correlation coefficient	0.88

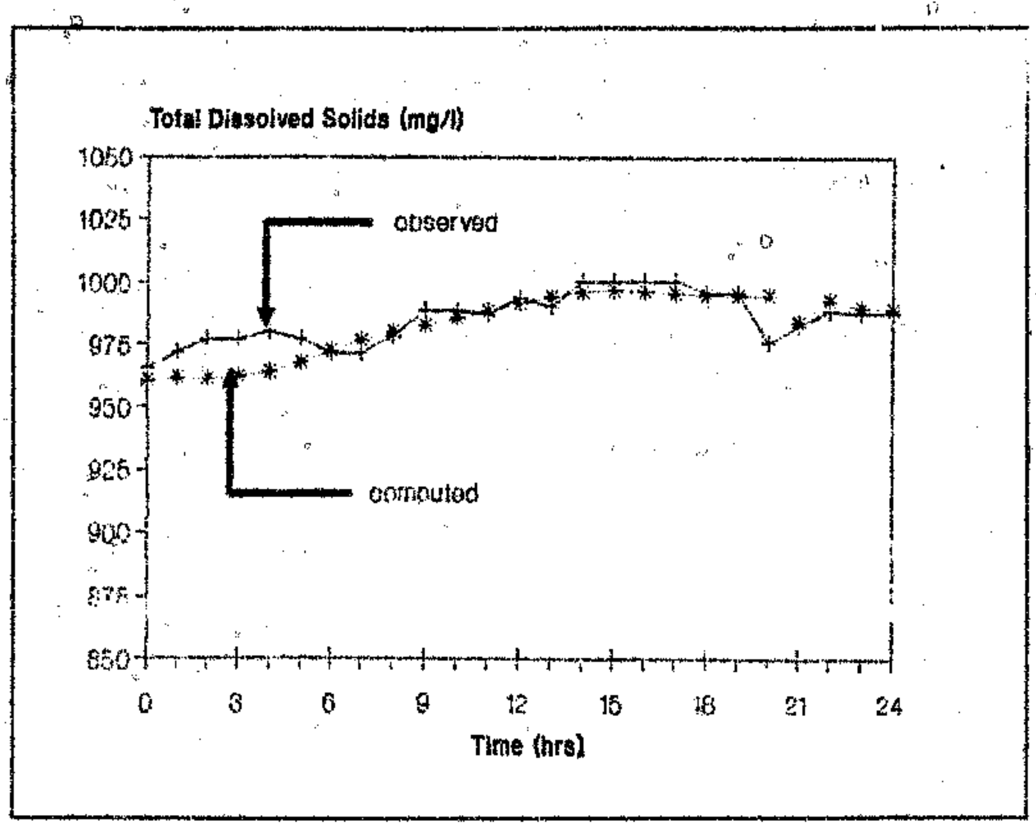


Figure 7.5 **Comparison of observed and computed TDS pollutographs for Klip river - July 18, 1978**

Inspection of the summary statistics and graphical comparison, indicate that no further adjustment was necessary. The most important and most representative statistics for the measure of agreement, that is, the coefficient of efficiency and the correlation coefficient, have properties closer to unity, hence indicating perfect agreement between observed data and computed results.

The following parameters were adopted :

- channel roughness $n = 0.040$
- weighting factor $\theta = 0.6$
- time step $\Delta t = 60$ min

Data for the second event was subsequently used to verify the model. Figure 7.6 overleaf, indicates the upstream TDS pollutograph (Boundary condition) for the event.

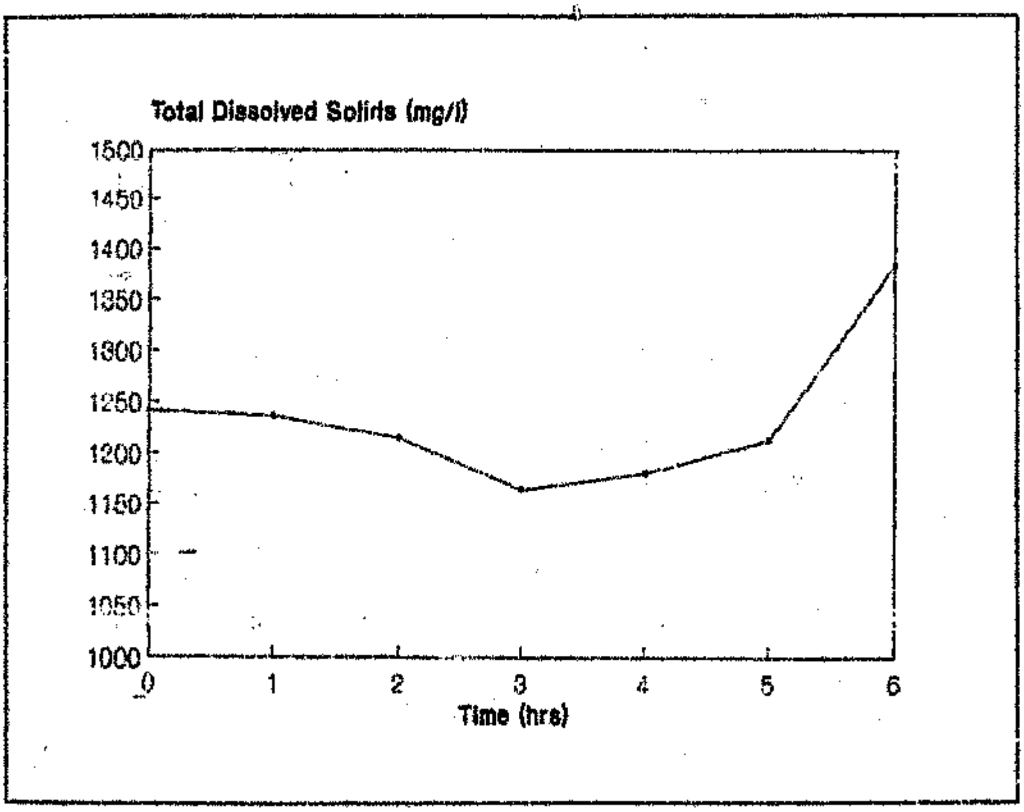


Figure 7.6 **Upstream inflow TDS pollutograph for the Klip river March 21, 1979**

The statistical analysis (Table 7.4) and graphical comparison (Figure 7.7) of the computed results and observed data were also undertaken for this event.

Table 7.4 **: Summary of statistical analysis for the Klip river March 21, 1979**

Statistic	Value
Mean of observed TDS (mg/l)	1235.92
Mean of computed TDS (mg/l)	1234.51
Ratio means (computed/observed)	0.99
Sum of squared residuals (mg^2/l^2)	7155.04
Sum of absolute residuals (mg/l)	199.42
Coefficient of efficiency	- 0.16
Correlation coefficient	0.88

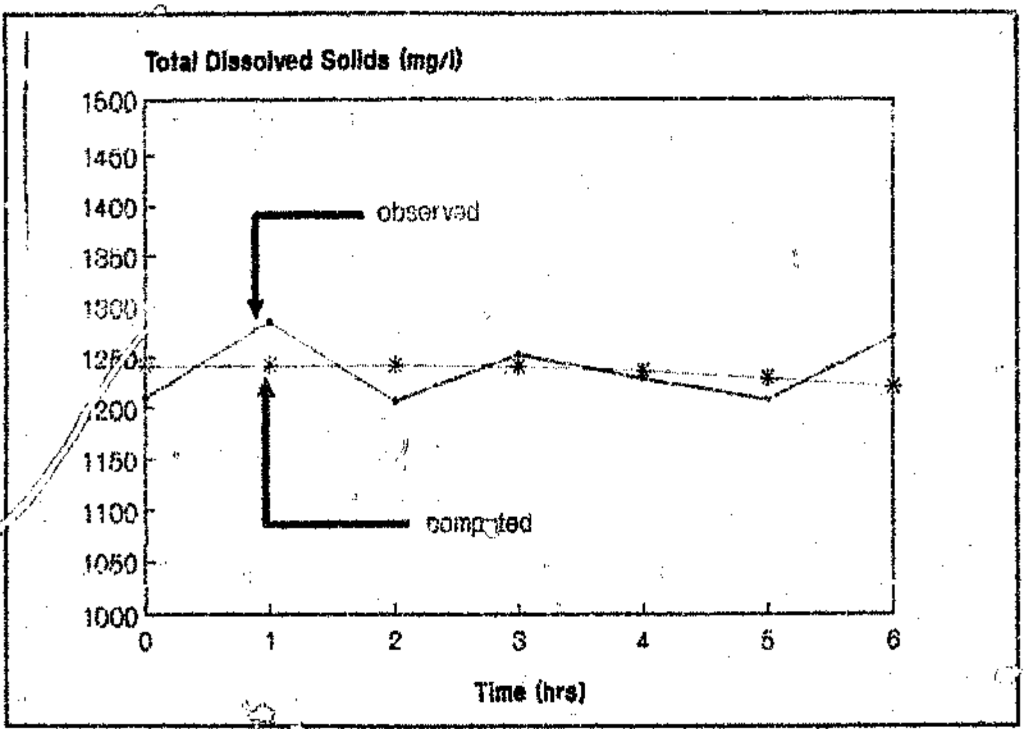


Figure 7.7 **Comparison of observed and computed TDS pollutographs for the Klip river March 21, 1979**

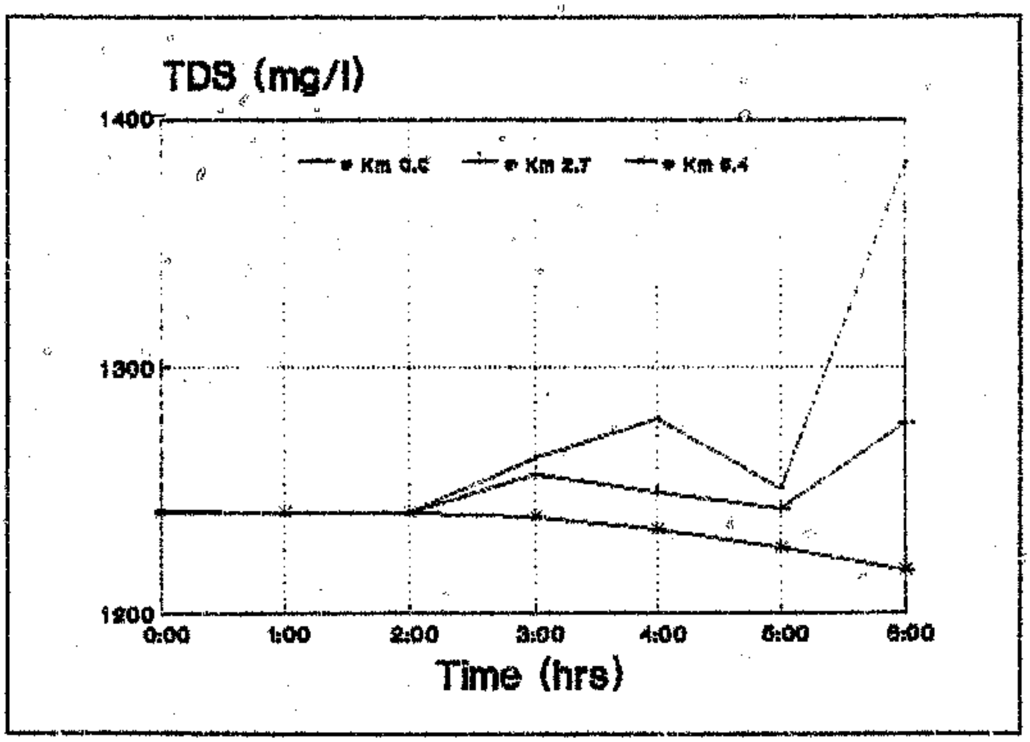


Figure 7.8 **TDS pollutographs at various locations along the Klip river study reach - March 21, 1979**

The results of this event are highlighted in Table 7.4 and Figure 7.7. As for the previous event the agreement of the computed and observed TDS was found to be fairly good. The ratio of computed mean TDS to observed mean TDS is equal to 0.99, whereas the correlation coefficient is equal to 0.88. Further, observation of Figure 7.8 indicates that:

- In the initial period of simulation (up to 2 hours) the TDS concentration is stable and the variation between the upstream and downstream limits is negligible.
- TDS pollutograph attenuation is more pronounced for periods of simulation greater than 2 hours (maximum attenuation of 12% at time = 6 hours).

7.4 Conclusions

The foregoing analysis indicate q[illegible]ly the capabilities of the proposed model in simulating joint transportation of hydrographs and pollutograph in open channels. Both the statistical and graphical comparison provided useful tools in the assessment of the model.

The following generalised conclusions have been made :

- The model presents the basic physics of nature effectively, noting the perfect agreement in observed data and computed results.

- The model is capable of computing the propagation of flood waves and conservative constituent concentration waves in watercourses.

- Flood and pollution routing can be accomplished by the same numerical scheme.

- Program computation yields results when $\theta \geq 0.5$.

- The stability and accuracy of the model was not greatly enhanced by the variation of θ from 0.6 to 1.0.

- Choice of $\Delta t/\Delta x$ is not critical for an implicit finite difference scheme, however this should not be chosen erratically.

- Realistic large time steps (Δt) do not influence the accuracy and stability of the results.

- Extensive data is required to successfully calibrate and verify the water quality model.

CHAPTER 8

8.0 CONCLUSIONS

8.1 Summary and Conclusions

Water quality modelling in urban watercourses is a relatively new field in South Africa although it is practised extensively in the developed countries, such as United States of America and Australia. The evaluation of design and management strategies for urban watercourses has traditionally been based on a single objective, namely that of hydraulic efficiency. The ongoing expansion and coalescing of our urban areas accompanied by deteriorating water quality could lead to adverse environmental effects, henceforth current practices need to be reviewed.

To assist in enhancing the understanding of water quality in urban watercourses, WATQUA model was developed. In conceiving the model the theory of unsteady flow and pollutant transport in open channels was investigated. The basic physics of the model comprises two sets of equations, namely, hydrodynamics and pollutant transport equations.

The diffusion approximation (inertial terms neglected) to Saint Venant equations was used for the hydrodynamics, whereas the mass balance equation was adopted for pollutant transport. Various numerical schemes for solution of the equations were investigated, thenceforth both equations were discretized using Preissmann four point implicit scheme and solve using a double sweep algorithm.

In compliance with the objectives of the study a WATQUA model implemented on an IBM compatible personal computer, and was compiled by Microsoft QUICKBASIC. The model comprises an advanced interactive interface ensuring ease and convenience of use.

The competence of the model was assessed with the aid of hypothetical and observed data in the Klip river, a typical urban watercourse in South Africa. The overall performance of WATQUA compared very favourably with observed data. It was shown that the model is capable of simulating a real-life situation with acceptable distortion.

The following generalized conclusions could be made:

- The proposed model is capable of satisfactorily simulating simultaneous routing of hydrographs and pollutographs, hence can be used as useful to enhance an understanding of water quality in watercourses.

- The model yield acceptable result, nearly as realistic as the most sophisticated one dimensional routing technique available in literature, namely, the complete dynamic wave model.

- The model indicates that there is a tendency for water quality to improve as one proceeds downstream.

- The model can predict time of travel and peak pollutant concentration.

- The model can be used successfully to assess the assimilative capacity of the urban watercourse system.

- The impacts of proposed development and natural occurrences in the urban watercourse can be predicted with the aid of the model.

- The ability of the watercourse to degrade dissolved substances can be evaluated by the model.

- The perfect agreement between observed and computed TDS suggest that the total mass transport is dominated by advection as diffusion was neglected in this study.

- The model presents a fast, cheap and effective tool to study the water quality aspects of watercourses.

8.2 Suggestion for Future Research

Based on the research work carried out in this project, the following recommendations have been made:

- Development of water quality model, incorporating the full dynamic wave model with additional features such as supercritical flow and rapidly varied flow capable of simulating chemical and biological processes.

- The measure of pollution from urban areas should be made with the purpose of assessing the quantity of pollution flowing from urban areas through the stormwater system.

- Sources of pollution should be identified and the quantity and nature of pollution recorder.

- The effect of urbanization on the total pollutant load into surface and ground water resources should be assessed.

- The implicit finite difference scheme should be retained in future model development as this enables unconditional choices of time and distance increments, and thus provides an efficient solution.

- Detail investigation of applicability of various steady state friction formulae for unsteady flow.

- Possibility of linking the water quality routines to the stormwater drainage routines should be investigated and implemented.

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APPENDIX A

LISTING OF PROGRAMS

```
'**********************************************************************
'*................ADVECTIVE WATER QUALITY MODEL ................*
'*................Developed by Musa S. Furumele.................*
'*....................MAIN DRIVING MODULE......................*
'*.........................Version 1.0.........................*
'*.........................March 1991...........................*
'**********************************************************************
 CLS : COLOR 7, 0
 IF ED$ = "OUTPUT" OR ED$ = "INPUT" THEN GOSUB MENU
 BOXN = 2: BOXTYPE = 0: YBOX = 3: XBOX = 13: BOXLEN = 60
 BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1: BEEP
 BOXN = 4: BOXTYPE = 0: YBOX = 6: XBOX = 15: BOXLEN = 54
 BOX$ = "": GOSUB BOX1: BEEP
 BOXN = 6: BOXTYPE = 0: YBOX = 7: XBOX = 16: BOXLEN = 52
 BOX$ = "Developed by M.S.Furumele": GOSUB BOX1: BEEP
 BOXN = 8: BOXTYPE = 0: YBOX = 8: XBOX = 18: BOXLEN = 42
 BOX$ = "Version 1.0": GOSUB BOX1: BEEP
 BOXN = 10: BOXTYPE = 0: YBOX = 9: XBOX = 20: BOXLEN = 44
 BOX$ = "September 1991 ": GOSUB BOX1: BEEP
 BOXN = 2: BOXTYPE = 0: YBOX = 11: XBOX = 22: BOXLEN = 40
 BOX$ = "": GOSUB BOX1:  BEEP
 BOXN = 1: BOXTYPE = 0: YBOX = 20: XBOX = 22: BOXLEN = 40
 BOX$ = "": GOSUB BOX1: BEEP
 COLOR 31: LOCATE 21, 30: PRINT "Press [Enter] to proceed"
 INPUT "", ED$: ED$ = INKEY$: IF ED$ = "" THEN 101
101  CLS : COLOR 7, 0: BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 16
 BOXLEN = 49: BOX$ = "": GOSUB BOX1
 BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 21: BOXLEN = 40
 BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
 LOCATE 8, 20:  PRINT "This model is based on the implicit solution"
 LOCATE 9, 20:  PRINT "of the Saint Venant (DIFFUSION approximation)"
 LOCATE 10, 20: PRINT "equations for unsteady flow and the mass"
 LOCATE 11, 20: PRINT "mass balance (allowing for decay) equation"
 LOCATE 12, 20: PRINT "for pollutant transport in open conduits."
 LOCATE 13, 20: PRINT ""
 LOCATE 14, 20: PRINT "The model calculates the time variations of"
 LOCATE 15, 20: PRINT "flow,water level and pollutant concentration"
 LOCATE 16, 20: PRINT "at specified positions along a river/stream"
 LOCATE 17, 20: PRINT "given the inflow hydrograph ,pollutograph and"
 LOCATE 18, 20: PRINT "riverine properties."
 BOXN = 1: BOXTYPE = 0: YBOX = 20: XBOX = 22: BOXLEN = 38
 BOX$ = "": GOSUB BOX1: BEEP
 COLOR 31: LOCATE 21, 30: PRINT "Press [ENTER] to proceed"
 INPUT "", ED$: ED$ = INKEY$: IF ED$ = "" THEN GOSUB MENU
MENU:  CLS : COLOR 2, 4: IF ED$ = "OUTPUT" THEN LOCATE 14, 31: COLOR
       31
```

```
     BOXN = 18: BOXTYPE = 0: YBOX = 3: XBOX = 17: BOXLEN = 46
     BOX$ = "": GOSUB BOX1
     BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
     BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
     BOXN = 1: BOXTYPE = 1: YBOX = 6: XBOX = 25: BOXLEN = 30
     BOX$ = " MAIN DRIVING MENU": GOSUB BOX1
     LOCATE 10, 30: PRINT "[ ].Input operations"
     LOCATE 12, 30: PRINT "[ ].Start simulation"
     LOCATE 14, 30: PRINT "[ ].Output operations"
     LOCATE 16, 30: PRINT "[ ].End session"
     LOCATE 10, 31: PRINT "I": LOCATE 12, 31: PRINT "S"
     LOCATE 14, 31: PRINT "O": LOCATE 16, 31: PRINT "E"
     COLOR 2, 2: BOXTYPE = 1: YBOX = 18: XBOX = 28
     BOXLEN = 24: BOX$ = " ENTER Selection :[ ]": GOSUB BOX1
     LOCATE 19, 49, 1, 1, 10
100  ED$ = INKEY$: IF ED$ = "" THEN 100
     IF ED$ = "I" OR ED$ = "i" THEN CHAIN "INPUT"
     IF ED$ = "S" OR ED$ = "s" THEN CHAIN "COMP"
     IF ED$ = "O" OR ED$ = "o" THEN CHAIN "OUTPUT"
     IF ED$ = "E" OR ED$ = "e" THEN END
     END
     '________________________________
BOX1: 'Draws box
     '--------
      COLOR 7, 0
      IF BOXTYPE = 0 THEN BOX1 = 201: BOX2 = 187: BOX3 = 200: BOX4 =
188: BOXU = 186: BOXL = 205
      IF BOXTYPE = 1 THEN BOX1 = 218: BOX2 = 191: BOX3 = 192: BOX4 =
217: BOXU = 179: BOXL = 196
      LOCATE YBOX, XBOX: PRINT CHR$(BOX1); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX2)
      FOR I = 1 TO BOXN
         YBOX = YBOX + 1
         LOCATE YBOX, XBOX: PRINT CHR$(BOXU);
         LOCATE YBOX, XBOX + BOXLEN + 1: PRINT CHR$(BOXU)
      NEXT I
      LOCATE YBOX, XBOX + (BOXLEN - LEN(BOX$)) / 2: PRINT BOX$;
      LOCATE YBOX + 1, XBOX: PRINT CHR$(BOX3); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX4);
      RETURN
      '____________________
```

```
'*****************************************************************
'*................ADVECTIVE WATER QUALITY MODEL .................*
'*................Developed by Musa S. Furumele.................*
'*....................INPUT HANDLING MODULE.....................*
'*.......................Version 1.0.........................*
'*.......................September 1991........................*
'*****************************************************************
    OPTION BASE 1
    DIM NCH(90), NP(90), LCH(90), X1(90, 50), Y1(90, 50)
    DIM QU(50), WLU(50), CU(50), CD(50), WLD(50), QD(50), T(50)
    DIM YMIN1(50), YMIN2(50), YMIN(50), YMAX(50), SO(50)
    DIM A(50), B(50)
    Y$ = SPACE$(10): K$ = Y$: SP = 10: BB$ = "C:": J$ = "**"
MENU: CLS : COLOR 7, 0
    BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
    BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 1: YBOX = 6: XBOX = 25: BOXLEN = 30
    BOX$ = " INPUT OPERATIONS MODULE": GOSUB BOX1
    LOCATE 10, 28: PRINT "[ ].Cross-section ....data"
    LOCATE 12, 28: PRINT "[ ].Boundary .........data"
    LOCATE 14, 28: PRINT "[ ].Display .....data echo"
    LOCATE 16, 28: PRINT "[ ].Print .......data echo"
    LOCATE 18, 28: PRINT "[ ].Exit .......... module"
    LOCATE 10, 29: PRINT "C": LOCATE 12, 29: PRINT "B"
    LOCATE 14, 29: PRINT "D": LOCATE 16, 29: PRINT "P"
    LOCATE 18, 29: PRINT "E"
    COLOR 2, 2: BOXTYPE = 1: YBOX = 20: XBOX = 27: BOXLEN = 26
    BOX$ = " ENTER Selection :[ ]": GOSUB BOX1
    LOCATE 21, 49, 1, 1, 10
100  ED$ = INKEY$: IF ED$ = "" THEN 100
    IF ED$ = "C" OR ED$ = "c" THEN GOSUB CSOP
    IF ED$ = "B" OR ED$ = "b" THEN GOSUB BDOP
    IF ED$ = "D" OR ED$ = "d" THEN GOSUB DISPC
    IF ED$ = "P" OR ED$ = "p" THEN GOSUB PRNC
    IF ED$ = "E" OR ED$ = "e" THEN CHAIN "DRIVE"
    END
    '------------------------------
CSOP: 'process...CROSS-SECTION data
    '------------------------------
    CLS : COLOR 7, 0
    BOXN = 21: BOXTYPE = 0: YBOX = 2: XBOX = 15: BOXLEN = 50
    BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 3: XBOX = 20: BOXLEN = 40
    BOX$ = " ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 1: YBOX = 5: XBOX = 25: BOXLEN = 30
    BOX$ = " CROSS-SECTION DATA ": GOSUB BOX1
```

```
        LOCATE 9, 29: PRINT "[ ].DISPLAY existing files"
        LOCATE 11, 29: PRINT "[ ].LOAD existing file"
        LOCATE 13, 29: PRINT "[ ].CREATE new file"
        LOCATE 15, 29: PRINT "[ ].EDIT data file --:-"; J$
        LOCATE 17, 29: PRINT "[ ].SAVE data file --:-"; J$
        LOCATE 19, 29: PRINT "[ ].QUIT to main menu"
        LOCATE 9, 30: PRINT "D": LOCATE 11, 30: PRINT "L"
        LOCATE 13, 30: PRINT "C": LOCATE 15, 30: PRINT "E"
        LOCATE 17, 30: PRINT "S": LOCATE 19, 30: PRINT "Q"
        BOXTYPE = 1: YBOX = 21: XBOX = 28: BOXLEN = 24
        BOX$ = " ENTER Selection : [ ]": GOSUB BOX1
        LOCATE 22, 49, 1, 1, 10
110     ED$ = INKEY$: IF ED$ = "" THEN 110
        IF (J$ = "" OR J$ = " " OR J$ = "**") AND (ED$ = "S" OR ED$ = "s") THEN
          GOSUB FDOP: GOSUB SAVEC1
        END IF
        IF ED$ = "D" OR ED$ = "d" THEN GOSUB DIR1
        IF ED$ = "L" OR ED$ = "l" THEN GOSUB LDC
        IF ED$ = "C" OR ED$ = "c" THEN MK = 1: GOSUB CCRS
        IF ED$ = "E" OR ED$ = "e" THEN GOSUB ECRS
        IF ED$ = "S" OR ED$ = "s" AND J$ = F$ THEN GOSUB SAVEC
        IF ED$ = "Q" OR ED$ = "q" THEN GOSUB MENU
        CLS : COLOR 7, 0: GOSUB CSOP: RETURN
        '---------------------------------------------
DIR1: 'DISPLAY existing Data files
        '---------------------------
        GOSUB CDRV: CLS : COLOR 7, 0
        BOXTYPE = 0: YBOX = 1: XBOX = 15: BOXLEN = 40
        BOX$ = "DYNAMIC WATER QUALITY MODEL": GOSUB BOX1
        BOXTYPE = 1: YBOX = 3: XBOX = 10: BOXLEN = 50
        BOX$ = "LIST OF DATA FILES ": GOSUB BOX1
        COLOR 7, 0: PRINT STRING$(78, 196): ON ERROR GOTO 150
        PRINT "---------------CROSS-SECTION----------------": COLOR 7, 0
        EXT = 1: FILES BB$ + "*.CS": ON ERROR GOTO 150
120     PRINT "-------------BOUNDARY CONDITION--------------": COLOR 7, 0
        EXT = 2: ON ERROR GOTO 150: FILES BB$ + "*.BC"
        ON ERROR GOTO 0
130     GOSUB DIR2: RETURN
DIR2:  LOCATE 23, 28: COLOR 31: PRINT "PRESS ANY KEY TO CONTINUE";
        COLOR 7, 0: BEEP
140     A$ = INKEY$: IF A$ = "" THEN 140 ELSE RETURN
150     RESUME 160
160     PRINT "No existing files...": BEEP
        ON ERROR GOTO 0: IF EXT = 1 THEN 120 ELSE 130
        RETURN
        '-------------------------------
CCRS: 'CREATE Cross-section data file
        '-------------------------------
```

```
    IF J$ = "**" OR J$ = "" OR J$ = " " THEN GOSUB FDOP: J$ = F$
    NCRS = 1        'Counter-Number of Cross-section.
170  CLS : COLOR 7, 0: ROW1 = 0
    BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
    BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 25: BOXLEN = 30
    BOX$ = "INPUT Cross-section data": GOSUB BOX1
    IF ROW1 > 20 THEN 220
    LOCATE 8, 26: PRINT "--------------------"
180  LOCATE 7, 26: INPUT "Cross-section no. = ", ED$
    IF ED$ = "" THEN 180
    CRS.ID = VAL(ED$)
    IF CRS.ID > 1 THEN
190    LOCATE 9, 26: INPUT "Reach length(m)  = ", ED$
       IF ED$ = "" THEN 190
       LCH(CRS.ID) = VAL(ED$)
    END IF
    NCH(CRS.ID) = .05  'Default value for Manning's roughness coefficient"
    LOCATE 10, 44: PRINT "0.050"
    COLOR 7, 0: LOCATE 10, 26: INPUT "Manning's 'n'... = ", ED$
    IF ED$ = "" THEN 200
    NCH(CRS.ID) = VAL(ED$)
200  NP(CRS.ID) = 4    'Default value number of points
    LOCATE 11, 45: PRINT "4"
    LOCATE 11, 26: INPUT "Number of points = ", ED$
    IF ED$ = "" THEN 210
    NP(CRS.ID) = VAL(ED$)
210  LOCATE 12, 26: PRINT "Co-ordinates of points"
    LOCATE 13, 26: PRINT "---------------------"
    FOR I2 = 1 TO NP(CRS.ID)
     ROW1 = (I2 + 13)
     IF ROW1 > 23 THEN
     IF I2 > 10 GOTO 230
     GOTO 170
     LOCATE 9, 26: PRINT "---------------------------"
220   LOCATE 8, 26: PRINT " Cross-section no. "; CRS.ID; " Continued "; ""
230   ROW1 = (I2 + 3)
     END IF
240   LOCATE ROW1, 26: PRINT "Point"; I2; "="
     LOCATE ROW1, 35: PRINT USING "##.##"; 0
     LOCATE ROW1, 36: INPUT "", ED$
     IF ED$ = "" THEN 240
     X1(CRS.ID, I2) = VAL(ED$)
     LOCATE ROW1, 43: PRINT ":"
250   LOCATE ROW1, 44: PRINT "Elevation"; I2; "="
     LOCATE ROW1, 57: PRINT USING "##.##"; 0
     LOCATE ROW1, 58: INPUT "", ED$
     IF ED$ = "" THEN 250
```

```
 Y1(CRS.ID, I2) = VAL(ED$)
NEXT I2
'-----------------------------
'Input another Cross-section
'-----------------------------
CLS : COLOR 7, 0
BOXN = 10: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
BOX$ = "": GOSUB BOX1
BOXN = 1: BOXTYPE = 0: YBOX = 5: XBOX = 25: BOXLEN = 30
BOX$ = "CROSS-SECTION : INPUT MODULE": GOSUB BOX1
BOXN = 1: BOXTYPE = 1: YBOX = 9: XBOX = 25: BOXLEN = 30
BOX$ = " ANOTHER CROSS-SECTION ? [ ]": GOSUB BOX1
260  LOCATE 10, 52: ED$ = INKEY$: IF ED$ = "" THEN 260
IF ED$ = "N" OR ED$ = "n" OR ED$ = "" THEN CLS : GOSUB CSOP
NCRS = NCRS + 1
GOTO 170
RETURN
'---------------------------
ECRS: 'EDIT Cross-section data
'-------------------------
IF J$ = "**" OR J$ = "" THEN
 CLS : COLOR 7, 0: BEEP
 BOXN = 15: BOXTYPE = 0: YBOX = 2: XBOX = 15: BOXLEN = 50
 BOX$ = "": GOSUB BOX1
 BOXN = 1: BOXTYPE = 0: YBOX = 3: XBOX = 20: BOXLEN = 40
 BOX$ = " ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
 BOXN = 1: BOXTYPE = 1: YBOX = 5: XBOX = 25: BOXLEN = 30
 BOX$ = " CROSS-SECTION DATA ": GOSUB BOX1
 BOXN = 3: BOXTYPE = 1: YBOX = 10: XBOX = 25: BOXLEN = 30
 BOX$ = "Press [Enter] to proceed": GOSUB BOX1: BEEP
 COLOR 31: LOCATE 11, 29: PRINT "Filename not specified": COLOR 7, 0
 INPUT "", ED$: ED$ = INKEY$: IF ED$ = "" THEN GOSUB FDOP
END IF
'-------------------------
UP:  'UPDATE a Cross-section
'-------------------------
CLS : COLOR 7, 0
BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
BOX$ = "": GOSUB BOX1
BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 25: BOXLEN = 30
BOX$ = "EDIT Cross-section data ": GOSUB BOX1
LOCATE 8, 28: PRINT "-------------------------"
270  LOCATE 7, 28: INPUT "Cross-section number = ", ED$
IF ED$ = "" THEN 270
I1 = VAL(ED$)
IF I1 > 1 THEN
  LOCATE 9, 26: PRINT "Reach length(m)  = "
  LOCATE 9, 44: PRINT USING "####.##"; LCH
```

```
      LOCATE 9, 44: INPUT "", LCH
    END IF
    COLOR 7, 0: LOCATE 10, 26: PRINT "Manning's 'n'... ="
    LOCATE 10, 45: PRINT USING "#.###"; NCH(I1)
    LOCATE 10, 45: INPUT "", NCH(I1)
    COLOR 7, 0: LOCATE 11, 26: PRINT "Number of points ="
    LOCATE 11, 44: PRINT NP(I1)
    LOCATE 11, 45: INPUT "", ED$
    IF ED$ = "" THEN 280
    NP(I1) = VAL(ED$)
280  COLOR 7, 0: LOCATE 12, 26: PRINT "Co-ordinates of points"
    LOCATE 13, 26: PRINT "----------------------"
    FOR I2 = 1 TO NP(I1)
      LOCATE (I2 + 13), 25: PRINT "Point"; I2; "="
      LOCATE (I2 + 13), 33: PRINT USING "###.##"; X1(I1, I2)
      LOCATE (I2 + 13), 35: INPUT "", X1(I1, I2)
      COLOR 7, 0: LOCATE (I2 + 13), 43: PRINT ":"
      LOCATE (I2 + 13), 43: PRINT "Elevation"; I2; "="
      LOCATE (I2 + 13), 56: PRINT USING "###.##"; Y1(I1, I2)
      LOCATE (I2 + 13), 56: INPUT "", Y1(I1, I2)
    NEXT I2
    BOXN = 1: BOXTYPE = 1: XBOX = 16: YBOX = 10: BOXLEN = 50
    BOX$ = "ANOTHER CROSS-SECTION (Y/N)  [ ] ": GOSUB BOX1
    LOCATE 17, 28: ED$ = INKEY$
    IF ED$ = "Y" OR ED$ = "y" THEN GOSUB UP ELSE RETURN
    '-----------------------------
FDOP: 'Filename and Drive Operation
    '-----------------------------
    CLS : COLOR 7, 0
    BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
    BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 1: YBOX = 6: XBOX = 25: BOXLEN = 30
    BOX$ = "NEW DATA FILES": GOSUB BOX1
    BOXN = 1: BOXTYPE = 1: YBOX = 9: XBOX = 25: BOXLEN = 30
    BOX$ = "Insert DATA DISK in DRIVE " + BB$: GOSUB BOX1
    LOCATE 13, 30: PRINT "ENTER FILENAME :": COLOR 31
    LOCATE 16, 25: PRINT "Press [Space Bar] to change DRIVE ": COLOR 7, 0
    LOCATE 19, 25: PRINT "     Press [ESC] to abort";
    LL = 0: CY = 13: CX = 47: K$ = F$
    X = 0: F$ = SPACE$(20): WLEN = 8
290  LOCATE CY, CX + X, 1
300  A$ = INKEY$: IF A$ = "" OR LEN(A$) = 2 THEN 290
    K = ASC(A$): IF K = 5 OR K = 12 OR K = 24 THEN 290
    IF (K = 13 AND X = 0) OR K = 27 THEN F$ = K$: RETURN
    IF A$ <> " " THEN 310
    IF BB$ = "A:" THEN BB$ = "B:" ELSE IF BB$ = "B:" THEN BB$ = "C:"
```

```
ELSE BB$ = "A:"
     COLOR 31: LOCATE 10, 52: PRINT BB$; : COLOR 7, 0: GOTO 290
310   IF K = 46 THEN 300
     IF K = 13 THEN F$ = LEFT$(F$, WLEN): T = 1: RETURN
320   IF X < 1 AND (K = WLEN) THEN LOCATE CY, CX: PRINT " ": LOCATE
CY, CX: BEEP: GOTO 290
     IF K = 39 OR K = WLEN THEN A$ = " ": GOTO 330
     X = X + 1: IF X > WLEN THEN X = WLEN: GOTO 290
     PRINT A$;
330   IF X = 0 THEN BEEP: GOTO 290
     MID$(F$, X, 1) = A$
     IF K = WLEN THEN LOCATE CY, CX + X: PRINT A$: X = X - 1: LOCATE
CY, CX + X: PRINT A$: LOCATE CY, CX + X
     GOTO 290
     J$ = F$
     CLS : COLOR 7, 0: RETURN
SAVEC1: RESET
     OPEN "I", #1, BB$ + F$ + ".CS": CLOSE #1
     LOCATE 16, 25: COLOR 31: PRINT "    Filename already in Diskette
"
     LOCATE 18, 25: PRINT "  [O]vewrite  [C]hange  [A]bort "; : COLOR 7, 0
340   A$ = INKEY$: IF A$ = "" THEN 340
     IF A$ = "O" OR A$ = "o" THEN K = 999: GOTO 350
     IF A$ = "C" OR A$ = "c" THEN
      J$ = "": GOSUB FDOP: GOSUB SAVEC: GOSUB CSOP
     END IF
     IF A$ = "A" OR A$ = "a" THEN
       F$ = K$: GOSUB CSOP
     END IF
     BEEP: GOTO 340
     RESUME 350
350   CLOSE : SV$ = F$: GOTO 360
     '-------------------
SAVEC: 'SAVE data into files
     '-------------------
     SV$ = J$
360   CLS : LOCATE 11, 38: PRINT "Saving"
     BOXN = 1: BOXTYPE = 0: YBOX = 13: XBOX = 32: BOXLEN = 17
     BOX$ = SV$ + ".CS": GOSUB BOX1
     SV = 1
     WLEN = INSTR(1, F$, ".")
     IF WLEN > 0 THEN F$ = LEFT$(F$, WLEN - 1)
     '-----------------------
     'Saving cross-section data
     '-----------------------
     OPEN "O", #1, BB$ + F$ + ".CS"
     PRINT #1, NCRS
     FOR I1 = 1 TO NCRS
```

```
     PRINT #1, I1, LCH, NCH(I1), NP(I1)
     FOR I2 = 1 TO NP(I1)
      PRINT #1, X1(I1, I2), Y1(I1, I2)
     NEXT I2
    NEXT I1
    CLOSE #1: J$ = F$: RETURN
    '-------------------------
DISPC: 'DISPLAY Cross-section data:
    '-------------------------
    GOSUB LDC: GOSUB LDB: CLS : COLOR 7, 0
    FOR I1 = 1 TO NCRS
     BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
     BOX$ = "": GOSUB BOX1
     BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 25: BOXLEN = 30
     BOX$ = " CROSS-SECTION DATA": GOSUB BOX1
     LOCATE 8, 32: PRINT "----------------"
370   LOCATE 7, 32: PRINT "Cross-section no. "
     LOCATE 7, 48: PRINT I1
     IF I1 > 1 THEN
       LOCATE 9, 30: PRINT "Reach length(m) = "
       LOCATE 9, 47: PRINT USING "#####.##"; LCH
     END IF
     LOCATE 10, 30: PRINT "Manning's 'n'   = "
     LOCATE 10, 48: PRINT USING "#.###"; NCH(I1)
     LOCATE 11, 30: PRINT "Co-ordinates of points"
     LOCATE 12, 30: PRINT "----------------------"
     FOR I2 = 1 TO NP(I1)
       ROW = 13
       COL = 8 * I2 + 20
       IF COL > 60 THEN
        ROW = ROW + 3: COL = 8 * I2 - 20
        IF I2 > 10 THEN ROW = ROW + 3: COL = 8 * I2 - 50
       END IF
        LOCATE ROW, 21: PRINT "Point"
        LOCATE ROW, COL + 1: PRINT "--"; I2; "--"
        LOCATE ROW + 1, 22: PRINT " X1="
        LOCATE ROW + 2, 22: PRINT " Y1="
        LOCATE ROW + 1, COL: PRINT USING "####.##"; X1(I1, I2)
        LOCATE ROW + 2, COL: PRINT USING "####.##"; Y1(I1, I2)
      NEXT I2
      BOXN = 1: BOXTYPE = 1: YBOX = 20: XBOX = 19: BOXLEN = 44
      BOX$ = "[A]bort OR view [N]ext OR [P]revious ": GOSUB BOX1
380    A$ = INKEY$
      IF A$ = "" THEN 380
      IF A$ = "A" OR A$ = "a" THEN 400
      IF A$ = "N" OR A$ = "n" THEN 390
      IF A$ = "P" OR A$ = "p" AND I1 > 1 THEN I1 = I1 - 1: GOTO 370
390   NEXT I1
```

```
400  BOXN = 1: BOXTYPE = 1: YBOX = 20: XBOX = 19: BOXLEN = 44
     BOX$ = "[A]bort OR view [B]oundary conditions": GOSUB BOX1
410  A$ = INKEY$
     IF A$ = "" THEN 410
     IF A$ = "A" OR A$ = "a" THEN GOSUB MENU
     IF A$ = "B" OR A$ = "b" THEN 420
420  CLS : COLOR 7, 0: BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15
     BOXLEN = 50: BOX$ = "": GOSUB BOX1
430  BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 25: BOXLEN = 32
     BOX$ = "BOUNDARY CONDITIONS": GOSUB BOX1
     IF ED$ = "$$1" THEN 490
     LOCATE 7, 25: PRINT "UPSTREAM CONDITIONS"
     LOCATE 8, 25: PRINT "-------------------"
     LOCATE 9, 25: PRINT "Simulation duration (mins) = "
     LOCATE 9, 53: PRINT USING "###.##"; SDU
440  LOCATE 10, 25: PRINT "Time step (mins)..........= "
     LOCATE 10, 53: PRINT USING "###.##"; TSU
450  FOR T% = 1 TO NTSU
     IF T% <= 10 THEN ROW = T% + 13
     IF T% > 10 AND T% <= 20 THEN ROW = T% + 3
     IF T% > 20 THEN ROW = T% - 7
     LOCATE 12, 20: PRINT "T (mins)": LOCATE 13, 20:   PRINT "--------"
     LOCATE 12, 30: PRINT "Q (cumecs)": LOCATE 13, 31: PRINT "--------"
     LOCATE 12, 43: PRINT "WL (m)": LOCATE 13, 43:     PRINT "--------"
     LOCATE 12, 53: PRINT "C (mg/l)": LOCATE 13, 53:   PRINT "--------"
     TIME = (T% - 1) * TSD: LOCATE ROW, 22: PRINT TIME
     LOCATE ROW, 29: PRINT USING "####.##"; QU(T%)
460  LOCATE ROW, 42: PRINT USING "###.##"; WLU(T%)
470  LOCATE ROW, 52: PRINT USING "###.##"; CU(T%)
480  NEXT T%
     LOCATE 22, 27: INPUT "Press [Enter] to continue", ED$
     ED$ = INKEY$: IF ED$ = "" THEN ED$ = "$$1": GOTO 430
490  LOCATE 7, 25: PRINT "DOWNSTREAM CONDITIONS"
     LOCATE 8, 25: PRINT "---------------------"
     LOCATE 9, 25: PRINT "Simulation duration (mins) = "
     LOCATE 9, 53: PRINT USING "###.##"; SDD
500  LOCATE 10, 25: PRINT "Time step (mins)..........= "
     LOCATE 10, 53: PRINT USING "###.##"; TSD
510  FOR T% = 1 TO NTSD
      IF T% <= 10 THEN ROW = T% + 13
      IF T% > 10 AND T% <= 20 THEN ROW = T% + 3
      IF T% > 20 THEN ROW = T% - 7
      LOCATE 12, 20: PRINT "T (mins)": LOCATE 13, 20:   PRINT "--------"
      LOCATE 12, 30: PRINT "Q (cumecs)": LOCATE 13, 31: PRINT "--------"
      LOCATE 12, 43: PRINT "WL (m)": LOCATE 13, 43:     PRINT "--------"
      LOCATE 12, 53: PRINT "C (mg/l)": LOCATE 13, 53:   PRINT "--------"
      TIME = (T% - 1) * TSD: LOCATE ROW, 22: PRINT TIME
      LOCATE ROW, 30: PRINT USING "###.##"; QD(T%)
```

```
520    LOCATE ROW, 42: PRINT USING "###.##"; WLD(T%)
530    LOCATE ROW, 52: PRINT USING "###.##"; CD(T%)
540   NEXT T%
     LOCATE 22, 27: INPUT "Press [Enter] to continue", ED$
     ED$ = INKEY$: IF ED$ = "" THEN GOSUB MENU
     RETURN
     '-------------------------------
PRNC: 'PRINT Cross-section data echo
     '-------------------------------
     GOSUB LDC
                         L P R I N T   S P C ( 5 ) ;
"=================================================================="
     LPRINT SPC(5); "ADVECTIVE WATER QUALITY MODEL "
     LPRINT ""
     LPRINT SPC(5); "Developed by Musa S.Furumele"
     LPRINT SPC(5); "Version 1.0"
     LPRINT SPC(5); "September 1991"
                         L P R I N T   S P C ( 5 ) ;
"=================================================================="
     LPRINT ""
     LPRINT SPC(5); "DESCRIPTION : "
     LPRINT ""
     LPRINT SPC(5); "------------------------"
     LPRINT SPC(5); "CROSS-SECTION DATA ECHO"
     LPRINT SPC(5); "FILENAME    :   "; J$ + ".CS"
     LPRINT SPC(5); "------------------------"
     LPRINT ""
     FOR I1 = 1 TO NCRS
      LPRINT SPC(5); "------------------------"
      LPRINT SPC(5); "Cross-section no."; I1
      LPRINT SPC(5); "------------------"
      LPRINT SPC(5); "Reach length (m) = "; USING "####.##"; LCH(I1)
      LPRINT SPC(5); "Manning's 'n'    = "; USING "#.###"; NCH(I1)
      LPRINT ""
      LPRINT SPC(5); "Co-ordinates"
      LPRINT SPC(5); "-----------"
      LPRINT SPC(5); "Point"; SPC(6); "X1(m)"; SPC(5); "Y1(m)"
      LPRINT SPC(5); "-----"; SPC(4); "------"; SPC(4); "------"
      FOR I2 = 1 TO NP(I1)
       LPRINT USING "####.##"; SPC(2); I2; SPC(4); X1(I1, I2); SPC(4); Y1(I1,
       NEXT I2
      LPRINT SPC(5); "------------------------"
     NEXT I1
     RETURN
     '-------------------------------------
PRNB: 'PRINT Boundary conditions data echo
     '-------------------------------------
                         L P R I N T   S P C ( 5 ) ;
```

```
"==================================================================="
    LPRINT SPC(5); "ADVECTION WATER QUALITY MODEL "
    LPRINT ""
    LPRINT SPC(5); "Developed by Musa S.Furumele"
    LPRINT SPC(5); "Version 1.0"
    LPRINT SPC(5); "September 1991"
                    L P R I N T    S P C ( 5 ) ;
"==================================================================="
    LPRINT ""
    LPRINT SPC(5); "DESCRIPTION : "
    LPRINT ""
    LPRINT SPC(5); "-----------------------------"
    LPRINT SPC(5); "BOUNDARY CONDITIONS DATA ECHO"
    LPRINT SPC(5); "FILENAME  : "; J$ + ".BC"
    LPRINT SPC(5); "-----------------------------"
    LPRINT ""
    LPRINT SPC(5); "------------------------------------------------------"
    LPRINT SPC(5); "-------------------"
    LPRINT SPC(5); "Upstream conditions"
    LPRINT SPC(5); "-------------------"
    LPRINT ""
    LPRINT SPC(5); "T(mins)"; "Q(cumecs)"; SPC(2); "WL(m)"; "C(mg/l)"
    LPRINT SPC(5); "-------"; "---------"; "-------"; "-------"
    FOR T% = 1 TO NTSU
     LPRINT SPC(5); T(T%); SPC(5); QU(T%); SPC(5); WLU(T%); SPC(5);
     CU(T%)
    NEXT T%
    LPRINT SPC(5); "------------------------------------------------------"
    LPRINT ""
    LPRINT SPC(5); "_____________________"
    LPRINT SPC(5); "Downstream conditions"
    LPRINT SPC(5); "---------------------"
    LPRINT SPC(5); ""
    LPRINT SPC(5); "T(mins)"; "Q(cumecs)"; SPC(2); "WL(m)"; "C(mg/l)"
    LPRINT SPC(5); "-------"; "---------"; "-------"; "-------"
    FOR T% = 1 TO NTSD
     LPRINT SPC(5); T(T%); SPC(5); QD(T%); SPC(5); WLD(T%); SPC(5); C(T%)
    NEXT T%
    LPRINT SPC(5); "------------------------------------------------------"
    GOSUB MENU: RETURN
    '---------------------
LDC: 'LOAD existing Data file
    '---------------------
    LL = 1: MRG = 0: GOSUB CDRV: CLS : COLOR 7, 0
    IF K = 27 THEN IF MRG > 0 THEN MRG = 0: GOTO CSO?
    BOXTYPE = 0: YBOX = 1: XBOX = 15: BOXLEN = 40
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXTYPE = 1: YBOX = 3: XBOX = 1: BOXLEN = 75: BOX$ = "": GOSUB
```

```
      BOX1
    X = 0: LOCATE 6, 1, 1, 12, 12: ON ERROR GOTO 720
    FILES BB$ + "*.CS": PRINT STRING$(77, CHR$(205))
550  ON ERROR GOTO 740
    BOXTYPE = 1: YBOX = 20: XBOX = 1: BOXLEN = 75: BOX$ = "": GOSUB
      BOX1
560  ON ERROR GOTO 0: LOCATE 21, 15: COLOR 31
    PRINT "[ESC] to Abort        [ENTER] to Confirm selection";
    COLOR 7, 0: K$ = F$: CY = 7: JY = 4: CX = 1: JX = 1
    F$ = "": WD = 12: FILE$ = "": TYP = 0
570  FILE$ = "": FOR Z = 1 TO 12
      FILE$ = FILE$ + CHR$(SCREEN(CY, CX + Z - 1))
    NEXT Z
    IF FILE$ = "            " THEN CX = JX: CY = JY: FILE$ = F$: GOTO 590
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 72 THEN BEEP: CY = CY - 1:
      GOTO 710
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 80 THEN 580 ELSE 590
580  BEEP: CY = CY + 1: GOTO 710
590  TYP = 0: LOCATE CY, CX: COLOR 0, 7: PRINT FILE$; : COLOR 7, 0
    LOCATE 4, 10: PRINT "Loading :": COLOR 31
    LOCATE 4, 20: PRINT "CROSS-SECTION DATA "
    LOCATE CY, CX: COLOR 31: PRINT FILE$; : COLOR 7, 0
    LOCATE 4, 40: PRINT "Filename: "; : COLOR 0, 7: PRINT FILE$
600  COLOR 7, 0: KK$ = INKEY$: IF KK$ = "" THEN 600
    IF LEN(KK$) = 1 THEN K = ASC(KK$) ELSE K = ASC(MID$(KK$, 2, 1))
    JY = CY: JX = CX: F$ = FILE$
    IF K = 27 THEN 610 ELSE 620
610     IF MRG <> 0 THEN MRG = 0: GOSUB CSOP ELSE MRG = 0
620     IF K <> 13 THEN 660
     IF MRG <> 3 THEN 650
     ON ERROR GOTO 640
630   MRG = 0: F$ = K$: GOSUB CSOP
640   RESUME 630
650   IF MRG = 0 THEN GOTO LC
660   IF K = 72 OR K = 5 THEN 670       'UP
     IF K = 80 OR K = 24 THEN 680      'DWN
     IF K = 77 OR K = 4 THEN 690       'RT
     IF K = 75 OR K = 19 THEN 700      'LF
     GOTO 600
670  IF CY <= 4 THEN 600 ELSE CY = CY - 1: GOTO 710
680  IF CY >= 24 THEN 600 ELSE CY = CY + 1: GOTO 710
690  IF CX >= 66 THEN 600 ELSE CX = CX + 18: GOTO 710
700  IF CX <= 1 THEN 600 ELSE CX = CX - 18: GOTO 710
710  LOCATE JY, JX: PRINT F$: GOTO 570
720  RESUME 730
730  X = X + 1
740  RESUME 750
750  IF X = 0 THEN GOSUB 560 ELSE LOCATE 12, 28: PRINT "No CRS "
```

```
    LOCATE 25, 1: PRINT STRING$(40, " "); : BEEP:     GOSUB DIR2
    LOCATE 22, 1: COLOR 7, 0: PRINT STRING$(78, CHR$(196))
      LC:   SV = 0: CLS : LOCATE 10, 37: PRINT "LOADING"
    BOXN = 1: BOXTYPE = 0: YBOX = 12: XBOX = 32: BOXLEN = 16
    BOX$ = F$ + ".CS": GOSUB BOX1
    OPEN "I", #1, BB$ + F$
    INPUT #1, NCRS
    FOR I1 = 1 TO NCRS
     INPUT #1, I1, LCH, NCH(I1), NP(I1)
     FOR I2 = 1 TO NP(I1)
      INPUT #1, X1(I1, I2), Y1(I1, I2)
     NEXT I2
    NEXT I1
    CLOSE #1: J$ = MID$(F$, 1, INSTR(F$, ".") - 1): RETURN
    '---------------------------------
BDOP: 'process..BOUNDARY CONDITIONS data
    '---------------------------------
    CLS : COLOR 7, 0
    BOXN = 21: BOXTYPE = 0: YBOX = 2: XBOX = 15: BOXLEN = 50
    BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 3: XBOX = 20: BOXLEN = 40
    BOX$ = " ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 1: YBOX = 5: XBOX = 25: BOXLEN = 30
    BOX$ = " BOUNDARY CONDITIONS DATA ": GOSUB BOX1
    LOCATE 9, 29: PRINT "[ ]..DISPLAY existing file"
    LOCATE 11, 29: PRINT "[ ]..LOAD exixting file"
    LOCATE 13, 29: PRINT "[ ]..CREATE new file"
    LOCATE 15, 29: PRINT "[ ]..EDIT data file--:-"; J$
    LOCATE 17, 29: PRINT "[ ]..SAVE data file--:-"; J$
    LOCATE 19, 29: PRINT "[ ]..QUIT to main menu"
    LOCATE 9, 30: PRINT "D": LOCATE 11, 30: PRINT "L"
    LOCATE 13, 30: PRINT "C": LOCATE 15, 30: PRINT "E"
    LOCATE 17, 30: PRINT "S": LOCATE 19, 30: PRINT "Q"
    BOXTYPE = 1: YBOX = 21: XBOX = 28: BOXLEN = 24
    BOX$ = " ENTER Selction : [ ]": GOSUB BOX1
    LOCATE 22, 49, 1, 1, 10
760  ED$ = INKEY$: IF ED$ = "" THEN 760
    IF (J$ = "" OR J$ = "**") AND (ED$ = "S" OR ED$ = "s") THEN
      GOSUB FDOP:  GOSUB SAVB1
    END IF
    IF ED$ = "D" OR ED$ = "d" THEN GOSUB DIR1
    IF ED$ = "L" OR ED$ = "l" THEN ED$ = "BC": GOSUB LDB
    IF ED$ = "C" OR ED$ = "c" THEN GOSUB INBD
    IF ED$ = "E" OR ED$ = "e" THEN GOSUB EBND
    IF ED$ = "S" OR ED$ = "s" AND J$ = F$ THEN ED$ = "BC": GOSUB SAVB
    IF ED$ = "Q" OR ED$ = "q" THEN GOSUB MENU
    CLS : COLOR 7, 0: GOSUB BDOP: RETURN
    '---------------------------------
```

```
INBD: 'INPUT Boundary Conditions data
    '------------------------------
    CLS : IF J$ <> F$ THEN GOSUB FDOP: J$ = F$: CLS : COLOR 7, 0
    BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
    BOX$ = "": GOSUB BOX1
770  BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 25
    BOXLEN = 32: BOX$ = "INPUT Boundary conditions data": GOSUB BOX1
    IF ED$ = "$$" THEN 810
    LOCATE 7, 25: PRINT "UPSTREAM CONDITIONS"
    LOCATE 8, 25: PRINT "-------------------"
    LOCATE 9, 51: PRINT USING "#.##"; 0
780  LOCATE 9, 25: INPUT "Simulation duration (mins) = ", ED$
    IF ED$ = "" THEN 780
    SDU = VAL(ED$)
790  LOCATE 10, 25: INPUT "Time step (mins).......... = ", ED$
    IF ED$ = "" THEN 790
    TSU = VAL(ED$)
    NTSU = INT(SDU / TSU) + 1
    FOR T% = 1 TO NTSU
     IF T% <= 10 THEN ROW = T% + 13
     IF T% > 10 AND T% <= 20 THEN ROW = T% + 3
     IF T% > 20 THEN ROW = T% - 7
     IF T% > 30 THEN ROW = T% - 17
     IF T% > 40 THEN ROW = T% - 27
     LOCATE 12, 20: PRINT "T (mins)": LOCATE 13, 20: PRINT "--------"
     LOCATE 12, 30: PRINT "Q (cumecs)": LOCATE 13, 31: PRINT "--------"
     LOCATE 12, 43: PRINT "WL (m)": LOCATE 13, 43: PRINT "------"
     LOCATE 12, 53: PRINT "C (mg/l)": LOCATE 13, 53: PRINT "--------"
800   TIME = (T% - 1) * TSU: LOCATE ROW, 22: PRINT TIME
     LOCATE ROW, 30: PRINT USING "###.##"; 0
     LOCATE ROW, 32: INPUT "", QU(T%)
     LOCATE ROW, 42: PRINT USING "###.##"; 0
     LOCATE ROW, 44: INPUT "", WLU(T%)
     LOCATE ROW, 52: PRINT USING "###.##"; 0
     LOCATE ROW, 54: INPUT "", CU(T%)
    NEXT T%
    ED$ = "$$": GOTO 770
810  LOCATE 7, 25: PRINT "DOWNSTREAM CONDITIONS"
    LOCATE 8, 25: PRINT "---------------------"
    LOCATE 9, 51: PRINT USING "#.##"; 0
820  LOCATE 9, 25: INPUT "Simulation duration (mins) = ", ED$
    IF ED$ = "" THEN 820
    SDD = VAL(ED$)
830  LOCATE 10, 25: INPUT "Time step (mins) ......... = ", ED$
    IF ED$ = "" THEN 830
    TSD = VAL(ED$)
    NTSD = INT(SDD / TSD) + 1
    FOR T% = 1 TO NTSD
```

```
      IF T% <= 10 THEN ROW = T% + 13
      IF T% > 10 AND T% <= 20 THEN ROW = T% + 3
      IF T% > 20 THEN ROW = T% - 7
      IF T% > 30 THEN ROW = T% - 17
      IF T% > 40 THEN ROW = T% - 27
      LOCATE 12, 20: PRINT "T (mins)": LOCATE 13, 20: PRINT "-------"
      LOCATE 12, 30: PRINT "Q (cumecs)": LOCATE 13, 31: PRINT "-------"
      LOCATE 12, 43: PRINT "WL (m)": LOCATE 13, 43: PRINT "-------"
      LOCATE 12, 53: PRINT "C (mg/l)": LOCATE 13, 53: PRINT "---------"
840    TIME = (T% - 1) * TSD: LOCATE ROW, 22: PRINT TIME
      LOCATE ROW, 30: PRINT USING "###.##"; 0
      LOCATE ROW, 32: INPUT "", QD(T%)
      LOCATE ROW, 42: PRINT USING "###.##"; 0
      LOCATE ROW, 44: INPUT "", WLD(T%)
      LOCATE ROW, 52: PRINT USING "###.##"; 0
      LOCATE ROW, 54: INPUT "", CD(T%)
    NEXT T%
    RETURN
    '-----------------------------------
EBND: 'EDIT Boundary conditions data
    '-----------------------------------
    IF J$ = "**" OR J$ = "" THEN
      CLS : COLOR 7, 0: BEEP
      BOXN = 15: BOXTYPE = 0: YBOX = 2: XBOX = 15: BOXLEN = 50
      BOX$ = "": GOSUB BOX1
      BOXN = 1: BOXTYPE = 0: YBOX = 3: XBOX = 20: BOXLEN = 40
      BOX$ = " ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
      BOXN = 1: BOXTYPE = 1: YBOX = 5: XBOX = 25: BOXLEN = 30
      BOX$ = " CROSS-SECTION DATA ": GOSUB BOX1
      BOXN = 3: BOXTYPE = 1: YBOX = 10: XBOX = 25: BOXLEN = 30
      BOX$ = "Press [Enter] to proceed": GOSUB BOX1: BEEP
      COLOR 31: LOCATE 11, 29: PRINT "Filename not specified": COLOR 7, 0
      INPUT "", ED$: ED$ = INKEY$: IF ED$ = "" THEN GOSUB FDOP
    END IF
    CLS : COLOR 7, 0: BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15
    BOXLEN = 50: BOX$ = "": GOSUB BOX1
850  BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 25: BOXLEN = 32
    BOX$ = "EDIT Boundary conditions data": GOSUB BOX1
    IF ED$ = "$$" THEN 910
    LOCATE 7, 25: PRINT "UPSTREAM CONDITIONS"
    LOCATE 8, 25: PRINT "-------------------"
    LOCATE 9, 25: PRINT "Simulation duration (mins) = "
    LOCATE 9, 53: PRINT USING "###.##"; SDU
    LOCATE 9, 54: INPUT "", ED$
    IF ED$ = "" THEN 860
    SDU = VAL(ED$)
860  LOCATE 10, 25: PRINT "Time step (mins)..........= "
    LOCATE 10, 55: PRINT USING "#.##"; TSU
```

```
    LOCATE 10, 55: INPUT "", ED$
    IF ED$ = "" THEN 870
    TSU = VAL(ED$)
870  FOR T% = 1 TO NTSU
     IF T% <= 10 THEN ROW = T% + 13
     IF T% > 10 AND T% <= 20 THEN ROW = T% + 3
     IF T% > 20 THEN ROW = T% - 7
    LOCATE 12, 20: PRINT "T (mins)": LOCATE 13, 20:  PRINT "--------"
    LOCATE 12, 30: PRINT "Q (cumecs)": LOCATE 13, 31: PRINT "--------"
    LOCATE 12, 43: PRINT "WL (m)": LOCATE 13, 43:    PRINT "--------"
    LOCATE 12, 53: PRINT "C (mg/l)": LOCATE 13, 53:  PRINT "--------"
    TIME = (T% - 1) * TSD: LOCATE ROW, 22: PRINT TIME
    LOCATE ROW, 29: PRINT USING "####.##"; QU(T%)
    LOCATE ROW, 31: INPUT "", ED$
    IF ED$ = "" THEN 880
    QU(T%) = VAL(ED$)
880  LOCATE ROW, 42: PRINT USING "###.##"; WLU(T%)
    LOCATE ROW, 43: INPUT "", ED$
    IF ED$ = "" THEN 890
    WLU(T%) = VAL(ED$)
890  LOCATE ROW, 52: PRINT USING "###.##"; CU(T%)
    LOCATE ROW, 54: INPUT "", ED$
    IF ED$ = "" THEN 900
    CU(T%) = VAL(ED$)
900  NEXT T%
    ED$ = "$$": GOTO 850
910  LOCATE 7, 25: PRINT "DOWNSTREAM CONDITIONS"
    LOCATE 8, 25: PRINT "---------------------"
    LOCATE 9, 25: PRINT "Simulation duration (mins) = "
    LOCATE 9, 53: PRINT USING "###.##"; SDD
    LOCATE 9, 54: INPUT "", ED$
    IF ED$ = "" THEN 920
    SDD = VAL(ED$)
920  LOCATE 10, 25: PRINT "Time step (mins)..........= "
    LOCATE 10, 55: PRINT USING "#.##"; TSD
    LOCATE 10, 55: INPUT "", ED$
    IF ED$ = "" THEN 930
    TSD = VAL(ED$)
930  FOR T% = 1 TO NTSD
      IF T% <= 10 THEN ROW = T% + 13
      IF T% > 10 AND T% <= 20 THEN ROW = T% + 3
      IF T% > 20 THEN ROW = T% - 7
      LOCATE 12, 20: PRINT "T (mins)": LOCATE 13, 20:  PRINT "--------"
      LOCATE 12, 30: PRINT "Q (cumecs)": LOCATE 13, 31: PRINT "--------"
      LOCATE 12, 43: PRINT "WL (m)": LOCATE 13, 43:    PRINT "--------"
      LOCATE 12, 53: PRINT "C (mg/l)": LOCATE 13, 53:  PRINT "--------"
      TIME = (T% - 1) * TSD: LOCATE ROW, 22: PRINT TIME
      LOCATE ROW, 30: PRINT USING "###.##"; QD(T%)
```

```
     LOCATE ROW, 31: INPUT "", ED$
     IF ED$ = "" THEN 940
     QD(T%) = VAL(ED$)
940    LOCATE ROW, 42: PRINT USING "###.##"; WLD(T%)
     LOCATE ROW, 42: INPUT "", ED$
     IF ED$ = "" THEN 950
     WLD(T%) = VAL(ED$)
950    LOCATE ROW, 52: PRINT USING "###.##"; CD(T%)
     LOCATE ROW, 52: INPUT "", ED$
     IF ED$ = "" THEN 960
     CD(T%) = VAL(ED$)
960  NEXT T%
    RETURN
SAVB1: RESET
    OPEN "I", #1, BB$ + F$ + ".BC": CLOSE #1
    LOCATE 16, 25: COLOR 31: PRINT "    Filename already in Diskette    "
    LOCATE 18, 25: PRINT "  [O]vewrite  [C]hange  [A]bort "; : COLOR 7, 0
970  A$ = INKEY$: IF A$ = "" THEN 970
    IF A$ = "O" OR A$ = "o" THEN K = 999: GOTO 980
    IF A$ = "C" OR A$ = "c" THEN
      J$ = "": GOSUB FDOP: GOSUB SAVB: GOSUB BDOP
    END IF
    IF A$ = "A" OR A$ = "a" THEN
      F$ = K$: GOSUB BDOP
    END IF
    BEEP: GOTO 970
    RESUME 980
980  CLOSE : SV$ = F$: GOTO 990
    RETURN
    '--------------------
SAVB: 'SAVE data into files
    '--------------------
    SV$ = J$
990  CLS : LOCATE 11, 38: PRINT "Saving"
    BOXN = 1: BOXTYPE = 0: YBOX = 13: XBOX = 32: BOXLEN = 17
    BOX$ = SV$ + ".BC": GOSUB BOX1
    SV = 1
    WLEN = INSTR(1, F$, ".")
    IF WLEN > 0 THEN F$ = LEFT$(F$, WLEN - 1)
    '------------------------------
    'Saving Boundary conditions data
    '------------------------------
1000  OPEN "O", #1, BB$ + F$ + ".BC"
    PRINT #1, SDU, TSU, NTSU
    FOR T% = 1 TO NTSU
      PRINT #1, T%, QU(T%), WLU(T%), CU(T%)
    NEXT T%
    PRINT #1, SDD, TSD, NTSD
```

```
     FOR T% = 1 TO NTSD
       PRINT #1, T%, QD(T%), WLD(T%), CD(T%)
     NEXT T%
     CLOSE #1: J$ = F$: RETURN
     '--------
BOX1: 'Draws box
     '---------
     COLOR 7, 0
     IF BOXTYPE = 0 THEN BOX1 = 201: BOX2 = 187: BOX3 = 200: BOX4 = 188:
BOXU = 186: BOXL = 205
     IF BOXTYPE = 1 THEN BOX1 = 218: BOX2 = 191: BOX3 = 192: BOX4 = 217:
BOXU = 179: BOXL = 196
     LOCATE YBOX, XBOX: PRINT CHR$(BOX1); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX2)
     FOR I = 1 TO BOXN
       YBOX = YBOX + 1
       LOCATE YBOX, XBOX: PRINT CHR$(BOXU);
       LOCATE YBOX, XBOX + BOXLEN + 1: PRINT CHR$(BOXU)
     NEXT I
     LOCATE YBOX, XBOX + (BOXLEN - LEN(BOX$)) / 2: PRINT BOX$;
     LOCATE YBOX + 1, XBOX: PRINT CHR$(BOX3); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX4);
     RETURN
     '---------------
CDRV: 'CHANGE Disk Drive
     '---------------
     CLS : COLOR 7, 0
     BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
     BOX$ = "": GOSUB BOX1
     BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
     BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
     BOXN = 1: BOXTYPE = 1: YBOX = 6: XBOX = 25: BOXLEN = 30
     BOX$ = "CROSS SECTION DATA": GOSUB BOX1
     BOXN = 1: BOXTYPE = 1: YBOX = 10: XBOX = 25: BOXLEN = 30
     BOX$ = "DATA will be LOADED From": GOSUB BOX1
     BOXTYPE = 1: YBOX = 14: XBOX = 34: BOXLEN = 12
     BOX$ = " Drive " + BB$: GOSUB BOX1
     LOCATE 18, 26: PRINT "Press           to change Drive"
     COLOR 31: LOCATE 18, 32: PRINT "SPACE BAR": COLOR 7, 0
     COLOR 7, 0: BOXTYPE = 1: YBOX = 20: XBOX = 25: BOXLEN = 31
      BOX$ = " Press [ENTER] to confirm": GOSUB BOX1: GOTO 1030
1010  LOCATE 21, 53
1020  K$ = INKEY$: IF K$ = "" THEN 1020 ELSE K = ASC(K$)
     IF K$ <> " " THEN 1040
     IF BB$ = "A:" THEN BB$ = "B:" ELSE IF BB$ = "B:" THEN BB$ = "C:" ELSE
BB$ = "A:"
1030  LOCATE 15, 43: PRINT BB$; : GOTO 1010
1040  IF K = 13 OR K = 27 THEN RETURN ELSE 1010
```

```
    '-------------------------------
LDB: 'LOAD existing Boundary Data file
    '-------------------------------
    LL = 1: MRG = 0: GOSUB CDRV: CLS : COLOR 7, 0
    IF K = 27 THEN IF MRG > 0 THEN MRG = 0: GOTO BDOP
    BOXTYPE = 0: YBOX = 1: XBOX = 15: BOXLEN = 40
    BOX$ = "DYNAMIC WATER QUALITY MODEL": GOSUB BOX1
    BOXTYPE = 1: YBOX = 3: XBOX = 1: BOXLEN = 75: BOX$ = "": GOSUB
BOX1
    X = 0: LOCATE 6, 1, 1, 12, 12: ON ERROR GOTO 1230
    FILES BB$ + "*.BC": PRINT STRING$(77, CHR$(205))
1050  ON ERROR GOTO 1250
    BOXTYPE = 1: YBOX = 20: XBOX = 1: BOXLEN = 75
    BOX$ = "": GOSUB BOX1
1060  ON ERROR GOTO 0: LOCATE 21, 15: COLOR 31
    PRINT "[ESC] to Abort        [ENTER] to Confirm selection";
    COLOR 7, 0: K$ = F$: CY = 7: JY = 4: CX = 1: JX = 1
    F$ = "": WD = 12: FILE$ = "": TYP = 0
1070  FILE$ = "": FOR Z = 1 TO 13
     FILE$ = FILE$ + CHR$(SCREEN(CY, CX + Z - 1))
    NEXT Z
    IF FILE$ = "             " THEN CX = JX: CY = JY: FILE$ = F$: GOTO 1090
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 72 THEN BEEP: CY = CY - 1:
GOTO 1220
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 80 THEN 1080 ELSE 1090
1080  BEEP: CY = CY + 1: GOTO 1220
1090  TYP = 0: LOCATE CY, CX: COLOR 0, 7: PRINT FILE$; : COLOR 7, 0
    LOCATE 4, 7: PRINT "Loading :"; : COLOR 31
    IF INSTR(FILE$, ".BC") > 0 THEN PRINT "BOUNDARY CONDITION DATA"
    LOCATE CY, CX: COLOR 31: PRINT FILE$; : COLOR 7, 0
    LOCATE 4, 43: PRINT "Filename: "; : COLOR 0, 7: PRINT FILE$;
    COLOR 7, 0
1100  KK$ = INKEY$: IF KK$ = "" THEN 1100
    IF LEN(KK$) = 1 THEN K = ASC(KK$) ELSE K = ASC(MID$(KK$, 2, 1))
    JY = CY: JX = CX: F$ = FILE$
    IF K = 27 THEN 1110 ELSE 1120
1110  IF MRG > 0 THEN MRG = 0: GOSUB BDOP ELSE MRG = 0
1120  IF K <> 13 THEN 1160
    IF MRG <> 3 THEN 1150
1130  MRG = 0: F$ = K$: GOSUB BDOP
1140  RESUME 1130
1150  IF MRG = 0 THEN GOTO LB
1160  IF K = 72 OR K = 5 THEN 1180                'UP
1170  IF K = 80 OR K = 24 THEN 1190     'DWN
    IF K = 77 OR K = 4 THEN 1200      'RT
    IF K = 75 OR K = 19 THEN 1210     'LF
    GOTO 1100
1180  IF CY <= 5 THEN 1100 ELSE CY = CY - 1: GOTO 1220
```

```
1190  IF CY >= 24 THEN 1100 ELSE CY = CY + 1: GOTO 1220
1200  IF CX >= 66 THEN 1100 ELSE CX = CX + 18: GOTO 1220
1210  IF CX <= 1 THEN 1100 ELSE CX = CX - 18: GOTO 1220
1220  LOCATE JY, JX: PRINT F$: GOTO 1070
1230  RESUME 1240
1240  X = X + 1: GOTO 1050
1250  RESUME 1260
1260  IF X = 0 THEN GOSUB 1060 ELSE LOCATE 12, 28: PRINT "No CRS or
BND Files"
     LOCATE 25, 1: PRINT STRING$(40, " "); : BEEP:  GOSUB DIR2
     LOCATE 22, 1: COLOR 7, 0: PRINT STRING$(78, CHR$(196))
LB:   SV = 0: CLS : LOCATE 10, 37: PRINT "LOADING"
     BOXN = 1: BOXTYPE = 0: YBOX = 12: XBOX = 32: BOXLEN = 16
     BOX$ = F$ + "BC": GOSUB BOX1
     OPEN "I", #1, BB$ + F$
     INPUT #1, SDU, TSU, NTSU
     FOR T% = 1 TO NTSU
      INPUT #1, T(T%), QU(T%), WLU(T%), CU(T%)
     NEXT T%
     INPUT #1, SDD, TSD, NTSD
     FOR T% = 1 TO NTSD
      INPUT #1, T(T%), QD(T%), WLD(T%), CD(T%)
     NEXT T%
     CLOSE #1: J$ = MID$(F$, 1, INSTR(F$, ".") - 1): RETURN
```

```
'*****************************************************************************
    '..............ADVECTIVE WATER QUALITY MODEL ..................
    '..............Developed by   M. S. Furumele..................
    '                  MAIN COMPUTATION MODULE
    '                      Version 1.00
    '                      JUNE 1991

'*****************************************************************************
    OPTION BASE 1
    DIM X1(70, 20), Y1(70, 20), NP(90), NCH(90), LCH(90), SO(90), T(100)
    DIM QU(100), WLU(100), CU(100), QD(100), WLD(100), CD(100)
    '------------------------------------------------------------------
    '               Loading data from files
    '               GOSUB CHDR: GOSUB LOAD
    '------------------------------------------------------------------
100  CLS : COLOR 7, 0: BOXN = 21: BOXTYPE = 0: YBOX = 2: XBOX = 15
    BOXLEN = 50: BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 3: XBOX = 20: BOXLEN = 40
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 5: XBOX = 25: BOXLEN = 30
    BOX$ = "SIMULATION  PARAMETERS": GOSUB BOX1
    '------------------------------------------------------------------
    '                 Simulation parameters
    '------------------------------------------------------------------
110  LOCATE 9, 30: INPUT "Duration  (mins) = ", SD$
    IF SD$ = "" THEN 110
    SD = VAL(SD$)
120  LOCATE 11, 30:   INPUT "Time step (mins) = ", TS$
    IF TS$ = "" THEN 120
    TS = VAL(TS$): TSP = 60 * TS
    NTS = INT(SD / TS) + 1
    LOCATE 13, 49: PRINT USING "#.##"; 1: 'default value for theta
    LOCATE 13, 30: INPUT "Theta.........   = ", TH$
    IF TH$ = "" THEN TH = 1: GOTO 130
    TH = VAL(TH$)
130  LOCATE 15, 49: PRINT USING "#.##"; .5:  'default value for Xi
    LOCATE 15, 30: INPUT "Xi............   = ", XI$
    IF XI$ = "" THEN XI = .5: GOTO 140
    XI = VAL(XI$)
    '------------------------------------------------------------------
    '                 Output filename
    '------------------------------------------------------------------
140  K$ = Y$: DR$ = "C:": GOSUB OFOP
    CLOSE : SV$ = F$: SV = 1
    WLEN = INSTR(1, F$, ".")
    IF WLEN > 0 THEN F$ = LEFT$(F$, WLEN - 1)
    OPEN "O", #1, DR$ + F$ + ".OUT"
    '------------------------------------------------------------------
```

```
'                 Choice of boundary conditions
'-----------------------------------------------------------------------
    CLS : COLOR 7, 0: BOXN = 21: BOXTYPE = 0: YBOX = 2: XBOX = 15
    BOXLEN = 50: BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 3: XBOX = 20: BOXLEN = 40
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 5: XBOX = 25: BOXLEN = 30
    BOX$ = "  BOUNDARY CONDITIONS": GOSUB B
    LOCATE 9, 33: PRINT "KNOWN HYDROGRAPHS"
    LOCATE 10, 33: PRINT "-----------------"
    LOCATE 12, 23: PRINT "[ ].Upstream stage and Downstream stage"
    LOCATE 14, 23: PRINT "[ ].Upstream flow and Downstream stage"
    LOCATE 16, 23: PRINT "[ ].Upstream stage and Downstream flow"
    LOCATE 18, 23: PRINT "[ ].Upstream flow and Downstream flow"
    LOCATE 12, 24: PRINT "1": LOCATE 14, 24: PRINT "2"
    LOCATE 16, 24: PRINT "3": LOCATE 18, 24: PRINT "4"
    BOXTYPE = 1: YBOX = 21: XBOX = 28: BOXLEN = 25
    BOX$ = " ENTER Selection : [ ]": GOSUB BOX1
    LOCATE 22, 50, 1, 1, 10
150 ED$ = INKEY$: IF ED$ = "" THEN 150
    IF ED$ = "1" THEN BOC = 1
    IF ED$ = "2" THEN BOC = 2
    IF ED$ = "3" THEN BOC = 3
    IF ED$ = "4" THEN BOC = 4

'=======================================================================
==========
'                 MAIN CALCULATION PROGRAM
'-----------------------------------------------------------------------
    REM $ DYNAMIC
    REDIM YMIN(NCRS), YMAX(NCRS), YMIN1(NCRS), YMIN2(NCRS),
YM(NCRS)
    REDIM PD(2 * NCRS), PL(2 * NCRS), PG(2 * NCRS), PX(2 * NCRS)
    REDIM DM(2 * NCRS), CM(2 * NCRS), EM(2 * NCRS), FM(2 * NCRS),
CS(NCRS)
    REDIM BM(2 * NCRS), AM(2 * NCRS), IQU(15 * NTS), IWLU(15 * NTS)
    REDIM ICU(15 * NTS), IQD(15 * NTS), IWLD(15 * NTS), IQD(15 * NTS)
    REDIM ICD(15 * NTS), WL(NCRS), PC(NCRS), V(NCRS), A(NCRS), B(NCRS)
    REDIM K(NCRS), PC(NCRS), PR.PC(NCRS), PR1.PC(NCRS), H(NCRS),
DWH(NTS)
    REDIM PR.H(NCRS), PR1.H(NCRS), Sf(NCRS), V.AVE(NCRS), B.AVE(NCRS)
    REDIM A.AVE(NCRS), K.AVE(NCRS), K(NCRS), PR.K(NCRS), PR1.B(NCRS)
    REDIM PR1.A(NCRS), PR1.V(NCRS), PR1.K(NCRS), PR.B(NCRS), PR.A(NCRS)
    REDIM PR.V(NCRS), PR.Q(NCRS), PR.WL(NCRS), PR.PC(NCRS),
PR1.PC(NCRS)
    REDIM PR1.Q(NCRS), PR1.WL(NCRS), C1(NCRS), C2(NCRS), C3(NCRS),
C4(NCRS)
    REDIM C5(NCRS), M1(NCRS), M2(NCRS), M3(NCRS), M4(NCRS), M5(NCRS)
```

```
    REDIM P1(NCRS), P2(NCRS), P3(NCRS), ITERH(NTS), ITERP(NTS),
A1(NCRS, NTS)
    REDIM Q1(NCRS, NTS), WL1(NCRS, NTS), V1(NCRS, NTS), PC1(NCRS, NTS)
    REDIM P3A(NCRS), P3B(NCRS), P3C(NCRS), QMAX(NCRS), WMAX(NCRS),
QMIN(NCRS)
    REDIM WMIN(NCRS), PMAX(NCRS), PMIN(NCRS), Q(NCRS),
K.AVE1(NCRS)
    REDIM A.AVE1(NCRS), B.AVE1(NCRS), V.AVE1(NCRS), PC.AVE(NCRS)
    '-----------------------------------------------------------------
    '          Interpolating boundary conditions for given time step
    IF TS <> TSD OR TS <> TSU THEN GOSUB INTP
    '-----------------------------------------------------------------
    PRINT #1, NCRS, SD, TS, NTS, TH, XI, PHI

'=========================================================================
==========
    '                    HYDRODYNAMICS SUB-MODEL
    '-----------------------------------------------------------------
    CLS : COLOR 7, 0: BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15
    BOXLEN = 60: BOX$ = "": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 50
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXN = 1: BOXTYPE = 0: YBOX = 7: XBOX = 28: BOXLEN = 35
    BOX$ = "HYDRODYNAMICS SUB-MODEL": GOSUB BOX1
    '-----------------------------------------------------------------
160 FOR T% = 1 TO NTS '...............START OF TIME LOOP.................
    '-----------------------------------------------------------------
     BOXN = 2: BOXTYPE = 0: YBOX = 11: XBOX = 28: BOXLEN = 35
     BOX$ = "PLEASE BE PATIENT": GOSUB BOX1
     LOCATE 12, 33: PRINT "CALCULATIONS IN PROGRESS"
     BOXN = 10: BOXTYPE = 1: YBOX = 10: XBOX = 25
     BOXLEN = 41: BOX$ = "": GOSUB BOX1
    '-----------------------------------------------------------------
    '                    Calculating initial variables
    '-----------------------------------------------------------------
     LOCATE 17, 33: PRINT "INITIALIZING OF VARIABLES"
     IF T% = 1 THEN Q1 = QU(1): GOSUB STEAD
     COLOR 7, 0: LOCATE 17, 33: PRINT "
    '-----------------------------------------------------------------
    '              Initial values from the previous time step
    '-----------------------------------------------------------------
     FOR I1 = 1 TO NCRS
       WL(I1) = PR.WL(I1): Q(I1) = PR.Q(I1)
       H(I1) = PR.H(I1): PR1.WL(I1) = WL(I1)
       PR1.Q(I1) = Q(I1): PR1.H(I1) = H(I1)
     NEXT I1
    '-----------------------------------------------------------------
     NITER = 50 '.............Default value for number of iterations
```

```
FOR ITER = 1 TO NITER '..........START OF ITERATION LOOP..........
'----------------------------------------------------------------
TM = (T% - 1) * TS
LOCATE 15, 36: PRINT "Theta.......= "; TH
LOCATE 16, 36: PRINT "Xi..........= "; XI
LOCATE 17, 36: PRINT "Time (mins)..= "; TM
LOCATE 18, 36: PRINT "Iteration....= "; ITER
'----------------------------------------------------------------
'............ SOLUTION OF THE HYDRODYNAMICS MATRIX...............
'                PENTADIAGONAL BANDED MATRIX
'----------------------------------------------------------------
GOSUB LINH  '...........linearizing equations...............
GOSUB COFH  '...........calculating coefficients...............
'--------------------------SOLUTION ALGORITHM------------------
GOSUB HMAT  '...........general arrangement of matrix..........
GOSUB DSWA  '...........double sweep algorithm.................
'----------------------------------------------------------------
IF BOC = 1 OR BOC = 3 THEN          ' Known upstream stage hydrograph
  WL(1) = WLU(T%)                  '--------------------------------
  H(1) = WL(1) - YM(1)
  Q(1) = PX(1)
ELSE                               '--------------------------------
  Q(1) = QU(T%)                     ' Known upstream flow hydrograph
  H(1) = PX(1)                     '--------------------------------
  WL(1) = YM(1) + H(1)
END IF
H(2) = PX(2)
WL(2) = YM(2) + H(2)
Q(2) = PX(3)
FOR U = 3 TO NCRS - 2
  Q(U) = PX(2 * U - 1)
  H(U) = PX(2 * U - 2)
  WL(U) = YM(U) + H(U)
NEXT U
Q(NCRS - 1) = PX(N - 1)
H(NCRS - 1) = PX(N - 2)
WL(NCRS - 1) = YM(NCRS - 1) + H(NCRS - 1)
IF BOC = 1 OR BOC = 2 THEN         '--------------------------------
  WL(NCRS) = WLD(T%)                ' Known downstream stage hydrograph
  H(NCRS) = WL(NCRS) - YM(NCRS) '--------------------------------
  Q(NCRS) = PX(N)
ELSE
  Q(NCRS) = QD(T%)                 '--------------------------------
  H(NCRS) = PX(N)                   ' Known downstream flow hydrograph
  WL(NCRS) = YM(NCRS) + H(NCRS) '--------------------------------
END IF
'----------------------------------------------------------------
'                Accuracy and stability check
```

```
'--------------------------------------------------------------------------
  ACCQ = .01: ACCH = .01
  DIF.MAXQ = 0: DIF.MAXH = 0
  FOR ACC = 1 TO NCRS
   IF WL(ACC) < YM(ACC) THEN
    BOXN = 8: BOXTYPE = 0: YBOX = 10: XBOX = 25
    BOXLEN = 41: BOX$ = "": GOSUB BOX1
    LOCATE 12, 33: PRINT "CALCULATIONS TERMINATED "
    LOCATE 13, 33: PRINT "        DUE TO          "
    LOCATE 15, 33: PRINT "  INSTABILITY PROBLEMS"
    LOCATE 16, 33: PRINT "CHECK DATA AND OR REVISE"
    LOCATE 17, 33: PRINT "  SIMULATION PARAMETERS"
    LOCATE 18, 33: PRINT "                        "
    LOCATE 20, 33: INPUT "Press [Enter] to continue", ED$
    IF ED$ = "" THEN 100
   END IF
   DIF.Q = ABS(Q(ACC) - PR1.Q(ACC))
   DIF.H = ABS(H(ACC) - PR1.H(ACC))
   IF DIF.MAXQ < DIF.Q THEN DIF.MAXQ = DIF.Q
   IF DIF.MAXH < DIF.H THEN DIF.MAXH = DIF.H
  NEXT ACC
  IF DIF.MAXQ <= ACCQ AND DIF.MAXH <= ACCH THEN 170
'--------------------------------------------------------------------------
'              Initialise before next iteration
'--------------------------------------------------------------------------
  FOR I1 = 1 TO NCRS
   PR1.WL(I1) = WL(I1)
   PR1.Q(I1) = Q(I1)
   PR1.H(I1) = H(I1)
  NEXT I1
 NEXT ITER   '.....END of iteration loop
'--------------------------------------------------------------------------
'        Initialise and store results before next time step
'--------------------------------------------------------------------------
170  ITERH(T%) = ITER
  FOR I1 = 1 TO NCRS
   WS = WL(I1)
   GOSUB CSPRP
   Q1(I1, T%) = Q(I1)
   WL1(I1, T%) = WL(I1)
   A1(I1, T%) = A(I1)
   V1(I1, T%) = V(I1)
   PRINT #1, Q1(I1, T%), WL1(I1, T%), V1(I1  T%), ITERH(T%)
   PR.WL(I1) = WL(I1)
   PR.Q(I1) = Q(I1)
   PR.H(I1) = H(I1)
  NEXT I1
  NEXT T%    '..........END OF TIME LOOP
```

```
'-----------------------------------------------------------------
'              POLLUTANT TRANSPORT SUB-MODEL
'-----------------------------------------------------------------
CLS : COLOR 3, 0: BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15
BOXLEN = 60: BOX$ = "": GOSUB BOX1
BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 50
BOX$ = "DYNAMIC WATER QUALITY MODEL": GOSUB BOX1
BOXN = 1: BOXTYPE = 0: YBCX = 7: XBOX = 28: BOXLEN = 35
BOX$ = "POLLUTANT TARNSPORT SUB-MODEL": GOSUB BOX1
'-----------------------------------------------------------------
FOR T% = 1 TO NTS '..................START OF TIME LOOP
'-----------------------------------------------------------------
BOXN = 2: BOXTYPE = 0: YBOX = 11: XBOX = 28: BOXLEN = 35
BOX$ = "PLEASE BE PATIENT": GOSUB BOX1
LOCATE 12, 33: PRINT "CALCULATIONS IN PROGRESS": COLOR 7, 0
BOXN = 10: BOXTYPE = 1: YBOX = 10: XBOX = 25: BOXLEN = 41
BOX$ = "": GOSUB BOX1: COLOR 7, 0
IF T% = 1 THEN
  FOR I1 = 1 TO NCRS
   PC(I1) = CU(T%)
   PR.PC(I1) = PC(I1)
   PR1.PC(I1) = PC(I1)
  NEXT I1
 END IF
'-----------------------------------------------------------------
'            Initial values from the previous time step
'-----------------------------------------------------------------
FOR I1 = 1 TO NCRS
 PR.PC(I1) = PC(I1)
 PR1.PC(I1) = PC(I1)
NEXT I1
'-----------------------------------------------------------------
NITER = 50          '.........Default number of iterations
FOR ITER = 1 TO NITER  '.........Start of iteration loop
'-----------------------------------------------------------------
 TM = (T% - 1) * TS
 LOCATE 15, 36: PRINT "Theta.......= "; TH
 LOCATE 16, 36: PRINT "Xi..........= "; XI
 LOCATE 17, 36: PRINT "Time (mins)..= "; TM
 LOCATE 18, 36: PRINT "Iteration....= "; ITER
'-----------------------------------------------------------------
'............SOLUTION OF THE POLLUTANT TRANSPORT MATRIX.............
'                TRIADIAGONAL BANDED MATRIX
'-----------------------------------------------------------------
GOSUB LINP  '............linearizing equations...................
GOSUB COFP  '............calculating coefficients................
'---------------------------SOLUTION ALGORITHM--------------------
GOSUB PMAT  '............general arrangement of matrix...........
```

```
GOSUB DSWA  '............double sweep algorithm..................
'---------------------------------------------------------------
PC(1) = CU(T%)
FOR U = 1 TO N
 PC(U + 1) = PX(U)
NEXT U
'-------------------------------------------------------------------
'                Accuracy and stability check
'-------------------------------------------------------------------
ACCP = 1: DIF.MAXPC = 0
FOR ACC = 1 TO NCRS
 DIF.PC = ABS(PC(ACC) - PR1.PC(ACC))
 IF DIF.MAXPC < DIF.PC THEN DIF.MAXPC = DIF.PC
NEXT ACC
IF DIF.MAXPC <= ACCP THEN 310
'-------------------------------------------------------------------
'            Initialise before next iteration
'-------------------------------------------------------------------
 FOR I1 = 1 TO NCRS
  PR1.PC(I1) = PC(I1)
 NEXT I1
NEXT ITER    '.....END of iteration
'-------------------------------------------------------------------
'Initialise and store results before next time step
'-------------------------------------------------------------------
310  ITERP(T%) = ITER
FOR I1 = 1 TO NCRS
 PC1(I1, T%) = PC(I1)
 PRINT #1, PC1(I1, T%), ITERP(T%)
 PR.PC(I1) = PC(I1)
NEXT I1
NEXT T%      '.......END of time loop
'-------------------------------------------------------------------
'           Calculating minimum and maximum values
'                   Bubble sort algorithm
'-------------------------------------------------------------------
FOR I1 = 1 TO NCRS
  FOR T% = 1 TO NTS - 1
   NTS1 = (NTS - T%)
   FOR T1% = 1 TO NTS1
     IF Q1(I1, T1%) <= Q1(I1, T1% + 1) THEN 555
      TEMPQ = Q1(I1, T1%)
      Q1(I1, T1%) = Q1(I1, T1% + 1)
      Q1(I1, T1% + 1) = TEMPQ
555    IF WL1(I1, T1%) <= WL1(I1, T1% + 1) THEN 666
      TEMPW = WL1(I1, T1%)
      WL1(I1, T1%) = WL1(I1, T1% + 1)
      WL1(I1, T1% + 1) = TEMPW
```

```
666       IF PC1(I1, T1%) <= PC1(I1, T1% + 1) THEN 777
          TEMP = PC1(I1, T1%)
          PC1(I1, T1%) = PC1(I1, T1% + 1)
          PC1(I1, T1% + 1) = TEMP
777       NEXT T1%
        NEXT T%
        QMAX(I1) = Q1(I1, NTS): QMIN(I1) = Q1(I1, 1)
        WMAX(I1) = WL1(I1, NTS): WMIN(I1) = WL1(I1, 1)
        PMAX(I1) = PC1(I1, NTS): PMIN(I1) = PC1(I1, 1)
        PRINT #1, QMAX(I1), QMIN(I1)
        PRINT #1, WMAX(I1), WMIN(I1)
        PRINT #1, PMAX(I1), PMIN(I1)
      NEXT I1
      '--------------------------------------------------------------------
             CLOSE #1: J$ = F$
      '     Proceed to driving menu
            ED$ = "OUTPUT": CHAIN "DRIVE"

'=====================================================================================
==========
      '              SUBROUTINES

'=====================================================================================
==========
DSWA: '              Double sweep algorithm solution
      '--------------------------------------------------------------------
        PD(1) = DM(1) / CM(1)
        PL(1) = EM(1) / CM(1)
        PG(1) = FM(1) / CM(1)
        PM = CM(2) - BM(2) * PD(1)
        PD(2) = (DM(2) - BM(2) * PL(1)) / PM
        PL(2) = EM(2) / PM
        PG(2) = (FM(2) - BM(2) * PG(1)) / PM
        FOR U = 3 TO N - 2
         PB = BM(U) - AM(U) * PD(U - 2)
         PM = CM(U) - PB * PD(U - 1) - AM(U) * PL(U - 2)
         PD(U) = (DM(U) - PB * PL(U - 1)) / PM
         PL(U) = EM(U) / PM
         PG(U) = (FM(U) - PB * PG(U - 1) - AM(U) * PG(U - 2)) / PM
        NEXT U
        PB = BM(N - 1) - AM(N - 1) * PD(N - 3)
        PM = CM(N - 1) - PB * PD(N - 2) - AM(N - 1) * PL(N - 3)
        PD(N - 1) = (DM(N - 1) - PB * PL(N - 2)) / PM
        PG(N - 1) = (FM(N - 1) - PB * PG(N - 2) - AM(N - 1) * PG(N - 3)) / PM
        PB = BM(N) - AM(N) * PD(N - 2)
        PM = CM(N) - PB * PD(N - 1) - AM(N) * PL(N - 2)
        PG(N) = (FM(N) - PB * PG(N - 1) - AM(N) * PG(N - 2)) / PM
        PX(N) = PG(N)
```

```
    PX(N - 1) = PG(N - 1) - PD(N - 1) * PX(N)
    FOR U = (N - 2) TO 1 STEP -1
     PX(U) = PG(U) - PD(U) * PX(U + 1) - PL(U) * PX(U + 2)
     NEXT U
    RETURN
    '------------------------------------------------------------
    '              Hydrodynamics sub-model
    '------------------------------------------------------------
INTP: '  1st....Interpolation of boundary values for chosen time step
    '------------------------------------------------------------
    DTP = 0
    FOR T1% = 1 TO NTS
     DTP = DTP + 1
     NTI = INT(TSU / TS)
     NTT = (NTS - 2) * NTI + 1
     IF T% = NTS THEN
      IQU = 0: INTQD = 0
      IWU = 0: INTWD = 0
      ICU = 0: INTCD = 0
      GOTO 240
     ELSE GOTO 230
230   END IF
     IQU = (QU(T1% + 1) - QU(T1%)) / NTI
     IWU = (WLU(T1% + 1) - WLU(T1%)) / NTI
     ICU = (CU(T1% + 1) - CU(T%)) / NTI
     IQD = (QD(T1% + 1) - QD(T1%)) / NTI
     IWD = (WLD(T1% + 1) - WLD(T1%)) / NTI
     ICD = (CD(T1% + 1) - CD(T1%)) / NTI
240   TINC = NTI * DTP - NTI
     DIP = 0
     TAC = NTI * DTP
     TINC = TINC + 1
     FOR TI% = TINC TO TAC
      IQU(TI%) = QU(T1%) + IQU * DIP
      IWLU(TI%) = WLU(T1%) + IWU * DIP
      ICU(TI%) = CU(T1%) + ICU * DIP
      IQD(TI%) = QD(T1%) + IQD * DIP
      IWLD(TI%) = WLD(T1%) + IWD * DIP
      ICD(TI%) = CD(T1%) + ICD * DIP
      DIP = DIP + 1
     NEXT TI%
     QU(T1%) = IQU(T1%): QD(T1%) = IQD(T1%)
     WLU(T1%) = IWLU(T1%): WLD(T1%) = IWLD(T1%)
     CU(T1%) = ICU(T1%): CD(T1%) = ICD(T1%)
     NEXT T1%
     RETURN
    '------------------------------------------------------------
STEAD: '  2nd....Calculation of initial conditions
```

```
'-----------------------------------------------------------------
'Evaluation  of low and high limits of Cross-  ction
'-----------------------------------------------------------------
'          *-----------* -- YMAX
'            *--------*   -- WL
'              *    *
'                *-*        -- YMIN
'-----------------------------------------------------------------
 FOR I1 = 1 TO NCRS
  FOR I2 = 2 TO NP(I1)
   IF (Y1(I1, I2 - 1) < Y1(I1, I2)) THEN 250
  NEXT I2
  FOR I2 = NP(I1) TO 2 STEP -1
   IF (Y1(I1, I2) > Y1(I1, I2 - 1)) THEN 260
  NEXT I2
250    YMIN1(I1) = Y1(I1, I2 - 1)
260    YMIN2(I1) = Y1(I1, I2 - 1)
   IF YMIN1(I1) > YMIN2(I1) THEN
    YMIN(I1) = YMIN2(I1)
   ELSE
    YMIN(I1) = YMIN1(I1)
   END IF
   YM(I1) = YMIN(I1)
   IF Y1(I1, 1) < Y1(I1, NP(I1)) THEN
     YMAX(I1) = Y1(I1, 1)
   ELSE
     YMAX(I1) = Y1(I1, NP(I1))
   END IF
 NEXT I1
 FOR I1 = 1 TO NCRS - 1
'-------------------------------------------------
'Evaluation of bed slope of channel
'-------------------------------------------------
  DIF = (YMIN(I1) - YMIN(I1 + 1))
  SO(I1 + 1) = DIF / LCH(I1 + 1)
 NEXT I1
 SO(1) = SO(2)
'-------------------------------------------------
 FOR I1 = 1 TO NCRS
270    WS = (YMIN(I1) + YMAX(I1)) / 2
  GOSUB CSPRP
  QMID = TCONV * SO(I1) ^ (1 / 2)
  DIFQ = ABS(QMID - Q1)
  WHILE DIFQ >= .01
  IF Q1 > QMID THEN
    YMIN(I1) = WS: GOTO 270
  ELSEIF Q1 < QMID THEN
    YMAX(I1) = WS: GOTO 270
```

```
      END IF
      WEND
      Q(I1) = QMID
      WL(I1) = WS
      H(I1) = WS - YM(I1)
      PR.H(I1) = H(I1)
      PR1.H(I1) = H(I1)
      PR.Q(I1) = Q(I1)
      PR.WL(I1) = WL(I1)
      PR1.Q(I1) = Q(I
      PR1.WL(I1) = WL(I1)
280    NEXT I1
      RETURN
'-------------------------------------------------------------------------
CSPRP: ' 3rd....Calculation of cross-section properties
'-------------------------------------------------------------------------
      LOCATE 19, 36: PRINT "Cross-section= "; I1
      TWP = 0: TCONV = 0: TAREA = 0: A(I1) = 0
      B(I1) = 0: TWIDTH = 0: TRAD = 0
      FOR I2 = 2 TO NP(I1)
       DIF1 = WS - Y1(I1, I2)
       DIF2 = WS - Y1(I1, I2 - 1)
       DIF3 = ABS(Y1(I1, I2) - Y1(I1, I2 - 1))
       DIF4 = ABS(X1(I1, I2) - X1(I1, I2 - 1))
      IF DIF1 <= 0 AND DIF2 < 0 THEN 290
      IF DIF1 > 0 AND DIF2 < 0 THEN
      XT = DIF4 * DIF1 / DIF3
      AREA = 1 / 2 * XT * DIF1
      WP = SQR(XT ^ 2 + DIF1 ^ 2)
      ELSEIF DIF1 < 0 AND DIF2 > 0 THEN
       XT = DIF4 * DIF2 / DIF3
       AREA = 1 / 2 * XT * DIF2
       WP = SQR(XT ^ 2 + DIF2 ^ 2)
      ELSEIF DIF1 >= 0 AND DIF2 >= 0 THEN
       XT = DIF4
       AREA = 1 / 2 * (DIF1 + DIF2) * DIF4
       WP = SQR(XT ^ 2 + DIF3 ^ 2)
      END IF
      RAD = AREA / WP
      ROUGH = NCH(I1)
      CONV = AREA * RAD ^ (2 / 3) / ROUGH
      TCONV = TCONV + CONV
      TAREA = TAREA + AREA
      TWP = TWP + WP
      TRAD = TRAD + RAD
      TWIDTH = TWIDTH + XT
290    NEXT I2
      WL(I1) = WS
```

```
    H(I1) = WL(I1) - YM(I1)
    K(I1) = TCONV
    A(I1) = TAREA
    B(I1) = TWIDTH
    V(I1) = Q(I1) / A(I1)
    RETURN
'-----------------------------------------------------------------
LINH: ' 4th....Linearisation of Hydrodynamics equations
'-----------------------------------------------------------------
    FOR I1 = 1 TO NCRS
     IF ITER = 1 THEN
      WS = PR.WL(I1)
      Q(I1) = PR.Q(I1)
      GOSUB CSPRP
      PR.H(I1) = H(I1)
      K.AVE1(I1) = K(I1)
      A.AVE1(I1) = A(I1)
      B.AVE1(I1) = B(I1)
      V.AVE1(I1) = V(I1)
      PR.K(I1) = K(I1)
      PR.V(I1) = V(I1)
      PR.B(I1) = B(I1)
      PR.A(I1) = A(I1)
     ELSE
      WS = PR1.WL(I1)
      Q(I1) = PR1.Q(I1)
      GOSUB CSPRP
      PR1.H(I1) = H(I1)
      K.AVE1(I1) = (1 - XI) * K(I1) + XI * PR.K(I1)
     END IF
    NEXT I1
    FOR I1 = 1 TO (NCRS - 1)
     IF ITER = 1 THEN
      B.AVE(I1) = (PR.B(I1) + PR.B(I1 + 1)) / 2
      A.AVE(I1) = (PR.A(I1) + PR.A(I1 + 1)) / 2
      V.AVE(I1) = (PR.V(I1) + PR.V(I1 + 1)) / 2
     ELSE
      B.AVE(I1) = (1 - XI) * (PR.B(I1) + PR.B(I1 + 1)) / 2
      B.AVE(I1) = B.AVE(I1) + XI * (B(I1) + B(I1 + 1)) / 2
      A.AVE(I1) = (1 - XI) * (PR.A(I1) + PR.A(I1 + 1)) / 2
      A.AVE(I1) = A.AVE(I1) + XI * (A(I1) + A(I1 + 1)) / 2
      V.AVE(I1) = (1 - XI) * (PR.V(I1) + PR.V(I1 + 1)) / 2
      V.AVE(I1) = V.AVE(I1) + XI * (V(I1) + V(I1 + 1)) / 2
     END IF
    NEXT I1
    RETURN
'-----------------------------------------------------------------
COFH: '5th....Calculation of coefficients for solution matrice
```

```
'-------------------------------------------------------------------
FOR I1 = 1 TO NCRS - 1
'Continuity equation
'------------------
 C1(I1) = B.AVE(I1) * LCH(I1 + 1)
 C2(I1) = -2 * TH * TSP
 C3(I1) = B.AVE(I1) * LCH(I1 + 1)
 C4(I1) = 2 * TH * TSP
 C5(I1) = 2 * (1 - TH) * TSP * (PR.Q(I1 + 1) - PR.Q(I1))
 C5(I1) = C5(I1) - B.AVE(I1) * LCH(I1 + 1) * (PR.H(I1 + 1) + PR.H(I1))
 C5(I1) = -C5(I1)
'-------------------------------------------------------------------
'Momentum equation
'----------------
 M1(I1) = -2 * 9.81 * A.AVE(I1) * TH * TSP
 M2(I1) = TH * ABS(PR.Q(I1)) / K.AVE1(I1) ^ 2
 M2(I1) = 9.81 * A.AVE(I1) * M2(I1) * TSP * LCH(I1 + 1)
 M3(I1) = 2 * 9.81 * A.AVE(I1) * TH * TSP
 M4(I1) = TH * ABS(PR.Q(I1 + 1)) / K.AVE1(I1 + 1) ^ 2
 M4(I1) = 9.81 * A.AVE(I1) * M4(I1) * TSP * LCH(I1 + 1)
 F1 = 2 * (1 - TH) * (PR.H(I1 + 1) - PR.H(I1)) * TSP
 F2 = PR.Q(I1 + 1) * ABS(PR.Q(I1 + 1)) / PR.K(I1 + 1) ^ 2
 F2 = (1 - TH) * F2 * TSP * LCH(I1 + 1)
 F3 = PR.Q(I1) * ABS(PR.Q(I1)) / PR.K(I1) ^ 2
 F3 = (1 - TH) * F3 * TSP * LCH(I1 + 1)
 F4 = -2 * SO(I1) * TSP * LCH(I1 + 1)
 M5(I1) = -9.81 * A.AVE(I1) * (F1 + F2 + F3 + F4)
'-------------------------------------------------------------------
NEXT I1
RETURN
'-------------------------------------------------------------------
HMAT: ' 6th....General arrangement of matrix
'-------------------------------------------------------------------
N = 2 * (NCRS - 1)
DM(1) = C3(1): EM(1) = C4(1)
CM(2) = M3(1): DM(2) = M4(1): EM(2) = 0
IF BOC = 1 OR BOC = 3 THEN
 CM(1) = C2(1)
 BM(2) = M2(1)
 FM(1) = C5(1) - C1(1) * (WLU(T%) - YM(1))
 FM(2) = M5(1) - M1(1) * (WLU(T%) - YM(1))
ELSE
 CM(1) = C1(1)
 BM(2) = M1(1)
 FM(1) = C5(1) - C2(1) * QU(T%)
 FM(2) = M5(1) - M2(1) * QU(T%)
END IF
FOR U = 4 TO (N - 2) STEP 2
```

```
  V = U / 2
  AM(U - 1) = 0: EM(U) = 0
  BM(U - 1) = C1(V): AM(U) = M1(V)
  CM(U - 1) = C2(V): BM(U) = M2(V)
  DM(U - 1) = C3(V): CM(U) = M3(V)
  EM(U - 1) = C4(V): DM(U) = M4(V)
  FM(U - 1) = C5(V): FM(U) = M5(V)
NEXT U
AM(N - 1) = 0
BM(N - 1) = C1(NCRS - 1)
CM(N - 1) = C2(NCRS - 1)
AM(N) = M1(NCRS - 1)
BM(N) = M2(NCRS - 1)
IF BOC = 1 OR BOC = 2 THEN
  DM(N - 1) = C4(NCRS - 1)
  CM(N) = M4(NCRS - 1)
  FM(N - 1) = C5(NCRS - 1) - C3(NCRS - 1) * (WLD(T%) - YM(NCRS))
  FM(N) = M5(NCRS - 1) - M3(NCRS - 1) * (WLD(T%) - YM(NCRS))
ELSE
  DM(N - 1) = C3(NCRS - 1)
  CM(N) = M3(NCRS - 1)
  FM(N - 1) = C5(NCRS - 1) - C4(NCRS - 1) * QD(T%)
  FM(N) = M5(NCRS - 1) - M4(NCRS - 1) * QD(T%)
END IF
RETURN

'===========================================================================
========
              Pollutant transport sub-model
  '----------------------------------------------------------------------
LINP: ' 7th...Linearisation of equations
   '-------------------------------
FOR I1 = 1 TO NCRS
 IF ITER = 1 THEN
   PC(I1) = PR.PC(I1)
 ELSE
   PC(I1) = PR1.PC(I1)
 END IF
NEXT I1
FOR I1 = 1 TO NCRS - 1
 IF ITER = 1 THEN
  PC.AVE(I1) = (PR.PC(I1 + 1) + PR.PC(I1)) / 2
 ELSE
  PC.AVE(I1) = (1 - TH) * (PR.PC(I1 + 1) + PR.PC(I1)) / 2
  PC.AVE(I1) = PC.AVE(I1 + 1) + TH * (PC(I1 + 1) + PC(I1)) / 2
  END IF
  NEXT I1
RETURN
```

```
    '-----------------------------------------------------------------------
COFP: '  8th....Calculations of coefficient for matrix
    '-----------------------------------------------------------------------
    FOR I1 = 1 TO NCRS - 1
    '-----------------------------------------------------------------------
     kp = 0
     P1(I1) = LCH(I1 + 1) - 2 * TH * V1(I1, T%) * TSP
     P2(I1) = LCH(I1 + 1) + 2 * TH * V1(I1, T%) * TSP
     P3A = 2 * kp * PC.AVE(I1) * LCH(I1 + 1) * TSP
     P3A = P3A - (PR.PC(I1 + 1) + PR.PC(I1)) * LCH(I1 + 1)
     AA = 2 * PC.AVE(I1) / A1(I1, T%)
     P3B = AA * TH * (Q1(I1 + 1, T%) - Q1(I1, T%)) * TSP
     IF T% = 1 THEN
       P3C = 0
     ELSE
      P3C = AA * (1 - TH) * (Q1(I1 + 1, T% - 1) - Q1(I1, T% - 1)) * TSP
     END IF
     P3D = 2 * V1(I1, T%) * (1 - TH) * (PR.PC(I1 + 1) - PR.PC(I1)) * TSP
     P3(I1) = -(P3A + P3B + P3C + PCD)
     NEXT I1
    RETURN
    '-----------------------------------------------------------------------
PMAT: '  9th....General arrangement of matrix
    '-----------------------------------------------------------------------
      N = (NCRS - 1)
      AM(1) = 0: BM(1) = 0
      CM(1) = P2(1)
      FM(1) = P3(1) - P1(1) * CU(T%)
      FOR U = 1 TO N
         AM(U) = 0
         DM(U) = 0
         BM(U) = 0
      NEXT U
      FOR U = 2 TO N
        BM(U) = P1(U)
        CM(U) = P2(U)
        FM(U) = P3(U)
      NEXT U
      RETURN

'===========================================================================
===
    '       Subroutines for input and output operations
    '---------------------------------------------------------------
CHDR: '  10th ....Change Disk drive
    '------------------------
    CLS : COLOR 7, 0: BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15
    BOXLEN = 50: BOX$ = "": GOSUB BOX1
```

```
      BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
      BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
      BOXN = 1: BOXTYPE = 0: YBOX = 6: XBOX = 25: BOXLEN = 30
      BOX$ = "SIMULATION PROGRAM": GOSUB BOX1
      BOXN = 1: BOXTYPE = 1: YBOX = 10: XBOX = 23: BOXLEN = 34
      BOX$ = "DATA will be LOADED from": GOSUB BOX1
      BOXTYPE = 1: YBOX = 14: XBOX = 34: BOXLEN = 12
      BOX$ = "Drive " + DR$: GOSUB BOX1: COLOR 31
      LOCATE 18, 25: PRINT "Press [SPACE BAR] to change Drive"
      COLOR 7, 0: BOXTYPE = 1: YBOX = 20: XBOX = 25: BOXLEN = 32
      BOX$ = " Press [Enter] to confirm": GOSUB BOX1: GOTO 360
340   LOCATE 21, 53
350   K$ = INKEY$: IF K$ = "" THEN 350 ELSE K = ASC(K$)
      IF K$ <> " " THEN 370
      IF DR$ = "A:" THEN DR$ = "B:" ELSE IF DR$ = "B:" THEN DR$ = "C:"
ELSE DR$ = "A:"
360   LOCATE 15, 4[illegible]: PRINT DR$; : GOTO 340
370   IF K = 13 OR K = 27 THEN RETURN ELSE 340
      RETURN
      '-----------------------------------
OFOP:   11th...Output file operations
      '-----------------------------------
      COLOR 7, 0: BOXN = 5: BOXTYPE = 1: YBOX = 16: XBOX = 20
      BOXLEN = 40: BOX$ = "": GOSUB BOX1
      BOXN = 1: BOXTYPE = 1: YBOX = 17: XBOX = 25: BOXLEN = 30
      BOX$ = "Store RESULTS in drive " + DR$: GOSUB BOX1
      LOCATE 20, 28: PRINT "Enter filename :": COLOR 31
      LOCATE 21, 25: PRINT "Press [space bar] to change drive "
      COLOR 7, 0: LOCATE 23, 25: PRINT "     Press [Enter] to continue     "
      LL = 0: CY = 20: CX = 45: K$ = F$
      X = 0: F$ = SPACE$(20): WLEN = 8
180   LOCATE CY, CX + X, 1
190   A$ = INKEY$: IF A$ = "" OR LEN(A$) = 2 THEN 180
      K = ASC(A$): IF K = 5 OR K = 12 OR K = 24 THEN 180
      IF (K = 13 AND X = 0) OR K = 27 THEN F$ = K$: RETURN
      IF A$ <> " " THEN 200
      IF DR$ = "A:" THEN DR$ = "B:" ELSE IF DR$ = "B:" THEN DR$ = "C:"
ELSE DR$ = "A:"
      COLOR 31: LOCATE 18, 51: PRINT DR$: COLOR 7, 0: GOTO 180
200   IF K = 46 THEN 190
      IF K = 13 THEN F$ = LEFT$(F$, WLEN): T = 1: RETURN
210   IF X < 1 AND (K = WLEN) THEN LOCATE CY, CX: PRINT " ": LOCATE
CY, CX: BEEP: GOTO 180
      IF K = 39 OR K = WLEN THEN A$ = " ": GOTO 220
      X = X + 1: IF X > WLEN THEN X = WLEN: GOTO 180
      PRINT A$;
220   IF X = 0 THEN BEEP: GOTO 180
      MID$(F$, X, 1) = A$
```

```
    IF K = WLEN THEN LOCATE CY, CX + X: PRINT A$: X = X - 1: LOCATE
CY, CX + X: PRINT A$: LOCATE CY, CX + X
    GOTO 180
    J$ = F$: CLS : COLOR 7, 0
    RETURN
    '----------------------------------------------------------------
LOAD: '  12th....Load existing data file
    '----------------------------------------------------------------
    'Cross-section data
    '-----------------
    LL = 1: MRG = 0: CLS : COLOR 7, 0
    IF K = 27 THEN IF MRG > 0 THEN MRG = 0: CHAIN "DRIVE"
    BOXTYPE = 0: YBOX = 1: XBOX = 15: BOXLEN = 40
    BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
    BOXTYPE = 1: YBOX = 3: XBOX = 1: BOXLEN = 75
    BOX$ = "": GOSUB BOX1
    X = 0: LOCATE 6, 1, 1, 12, 12: ON ERROR GOTO 560
    FILES DR$ + "*.CS": PRINT STRING$(77, CHR$(205))
380  ON ERROR GOTO 580
    BOXTYPE = 1: YBOX = 20: XBOX = 1: BOXLEN = 75
    BOX$ = "": GOSUB BOX1
390  ON ERROR GOTO 0: LOCATE 21, 15: COLOR 31
    PRINT " [Esc] to Abort       [Enter] to confirm selection";
    COLOR 7, 0: K$ = F$: CY = 7: JY = 4: CX = 1: JX = 1
    F$ = "": WD = 12: FILE$ = "": TYP = 0
400  FILE$ = "": FOR Z = 1 TO 12
    FILE$ = FILE$ + CHR$(SCREEN(CY, CX + Z - 1))
    NEXT Z
    IF FILE$ = "            " THEN CX = JX: CY = JY: FILE$ = F$: GOTO 430
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 72 THEN BEEP: CY = CY - 1:
GOTO 550
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 80 THEN 420 ELSE GOTO 430
420  BEEP: CY = CY + 1: GOTO 550
430  TYP = 0: LOCATE CY, CX: COLOR 0, 7: PRINT FILE$; : COLOR 7, 0
    LOCATE 4, 10: PRINT "Loading :"; : COLOR 31
    IF INSTR(FILE$, ".CS") > 0 THEN PRINT "CROSS-SECTION"
    LOCATE CY, CX: COLOR 31: PRINT FILE$: COLOR 7, 0
    LOCATE 4, 40: PRINT "Filename: "; : COLOR 0, 7: PRINT FILE$;
440  COLOR 7, 0: KK$ = INKEY$: IF KK$ = "" THEN 440
    IF LEN(KK$) = 1 THEN K = ASC(KK$) ELSE K = ASC(MID$(KK$, 2, 1))
    JY = CY: JX = CX: F$ = FILE$
    IF K = 27 THEN 450 ELSE 460
450  IF MRG <> 0 THEN MRG = 0: CHAIN "DRIVE" ELSE MRG = 0
460  IF K <> 13 THEN 500
    IF MRG <> 3 THEN 490
    ON ERROR GOTO 480
470  MRG = 0: F$ = K$: CHAIN "DRIVE"
480  RESUME 470
```

```
490  IF MRG = 0 THEN 600
500  IF K = 72 OR K = 5 THEN 510    'UP
     IF K = 80 OR K = 24 THEN 520  'DOWN
     IF K = 77 OR K = 4 THEN 530   'RIGHT
     IF K = 75 OR K = 19 THEN 540  'LEFT
     GOTO 440
510  IF CY <= 4 THEN 440 ELSE CY = CY - 1: GOTO 550
520  IF CY >= 24 THEN 440 ELSE CY = CY + 1: GOTO 550
530  IF CX >= 66 THEN 440 ELSE CX = CX + 18: GOTO 550
540  IF CX <= 1 THEN 440 ELSE CX = CX - 18: GOTO 550
550  LOCATE JY, JX: PRINT F$: GOTO 400
560  RESUME 570
570  X = X + 1: GOTO 380
580  RESUME 590
590  IF X = 0 THEN GOSUB 390 ELSE LOCATE 12, 28: PRINT "NO CS Files"
     LOCATE 25, 1: PRINT STRING$(40, " "); : BEEP: 'GOSUB DIR2
     LOCATE 22, 1: COLOR 7, 0: PRINT STRING$(78, CHR$(196))
600  SV = 0: CLS : LOCATE 10, 37: PRINT LOADING
     BOX$ = F$ + ".CS": GOSUB BOX1
     OPEN "I", #1, DR$ + F$
     INPUT #1, NCRS
     FOR I1 = 1 TO NCRS
      INPUT #1, I1, LCH(I1), NCH(I1), NP(I1)
      FOR I2 = 1 TO NP(I1)
        INPUT #1, X1(I1, I2), Y1(I1, I2)
      NEXT I2
     NEXT I1
     CLOSE #1: J$ = MID$(F$, 1, INSTR(F$, ".") - 1)
     '------------------------
     'Boundary conditions data
     '------------------------
     LL = 1: MRG = 0: GOSUB CHDR: CLS : COLOR 0, 7
     IF K = 27 THEN IF MRG > 0 THEN MRG = 0: CHAIN "DRIVE"
     BOXTYPE = 0: YBOX = 1: XBOX = 15: BOXLEN = 40
     BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
     BOXTYPE = 1: YBOX = 3: XBOX = 1: BOXLEN = 75
     BOX$ = "": GOSUB BOX1
     X = 0: LOCATE 6, 1, 1, 12, 12: ON ERROR GOTO 780
     FILES DR$ + "*.BC": PRINT STRING$(77, CHR$(205))
610  ON ERROR GOTO 800
     BOXTYPE = 1: YBOX = 20: XBOX = 1: BOXLEN = 75
     BOX$ = "": GOSUB BOX1
620  ON ERROR GOTO 0: LOCATE 21, 15: COLOR 31
     PRINT " [Esc] to Abort      [Enter] to confirm selection";
     COLOR 7, 0: K$ = F$: CY = 7: JY = 4: CX = 1: JX = 1
     F$ = "": WD = 12: FILE$ = "": TYP = 0
630  FILE$ = "": FOR Z = 1 TO 12
     FILE$ = FILE$ + CHR$(SCREEN(CY, CX + Z - 1))
```

```
    NEXT Z
    IF FILE$ = "        " THEN CX = JX: CY = JY: FILE$ = F$: GOTO 650
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 72 THEN BEEP: CY = CY - 1:
GOTO 770
    IF INSTR(FILE$, CHR$(205)) > 0 AND K = 80 THEN 640 ELSE GOTO 650
640  BEEP: CY = CY + 1: GOTO 770
650  TYP = 0: LOCATE CY, CX: COLOR 0, 7: PRINT FILE$; : COLOR 7, 0
    LOCATE 4, 10: PRINT "Loading :"; : COLOR 31
    IF INSTR(FILE$, ".BC") > 0 THEN PRINT "BOUNDARY CONDITIONS
DATA"
    LOCATE CY, CX: COLOR 31: PRINT FILE$: COLOR 7, 0
    LOCATE 4, 40: PRINT "Filename: "; : COLOR 0, 7: PRINT FILE$;
660  COLOR 7, 0
: KK$ = INKEY$: IF KK$ = "" THEN 660
    IF LEN(KK$) = 1 THEN K = ASC(KK$) ELSE K = ASC(MID$(KK$, 2, 1))
    JY = CY: JX = CX: F$ = FILE$
    IF K = 27 THEN 670 ELSE 680
670  IF MRG <> 0 THEN MRG = 0: CHAIN "DRIVE" ELSE MRG = 0
680  IF K <> 13 THEN 720
    IF MRG <> 3 THEN 710
    ON ERROR GOTO 700
690  MRG = 0: F$ = K$: CHAIN "DRIVE"
700  RESUME 690
710  IF MRG = 0 THEN 820
720  IF K = 72 OR K = 5 THEN 730    'UP
    IF K = 80 OR K = 24 THEN 740  'DOWN
    IF K = 77 OR K = 4 THEN 750   'RIGHT
    IF K = 75 OR K = 19 THEN 760  'LEFT
    GOTO 660
730  IF CY <= 4 THEN 660 ELSE CY = CY - 1: GOTO 770
740  IF CY >= 24 THEN 660 ELSE CY = CY + 1: GOTO 770
750  IF CX >= 66 THEN 660 ELSE CX = CX + 18: GOTO 770
760  IF CX <= 1 THEN 660 ELSE CX = CX - 18: GOTO 770
770  LOCATE JY, JX: PRINT F$: GOTO 630
780  RESUME 790
790  X = X + 1: GOTO 610
800  RESUME 810
810  IF X = 0 THEN GOSUB 620 ELSE LOCATE 12, 28: PRINT "NO BD Files"
    LOCATE 25, 1: PRINT STRING$(40, " "); : BEEP: 'GOSUB DIR2
    LOCATE 22, 1: COLOR 7, 0: PRINT STRING$(78, CHR$(196))
820  SV = 0: CLS : LOCATE 10, 37: PRINT LOADING
    BOX$ = F$ + ".BC": GOSUB BOX1
    OPEN "I", #1, DR$ + F$
    INPUT #1, SDU, TSU, NTSU
    FOR T% = 1 TO NTSU
     INPUT #1, T(T%), QU(T%), WLU(T%), CU(T%)
    NEXT T%
    INPUT #1, SDD, TSD, NTSD
```

```
    FOR T% = 1 TO NTSD
     INPUT #1, T(T%), QD(T%), WLD(T%), CD(T%)
    NEXT T%
    CLOSE #1, J$ = MID$(F$, 1, INSTR(F$, ".") - 1)
    RETURN
'---------------
BOX1: ' 13....Draw box
'---------------
    COLOR 7, 0
    IF BOXTYPE = 0 THEN
      BOX1 = 201: BOX2 = 187: BOX3 = 200
      BOX4 = 188: BOXU = 186: BOXL = 205
    END IF
    IF BOXTYPE = 1 THEN
      BOX1 = 218: BOX2 = 191: BOX3 = 192
      BOX4 = 217: BOXU = 179: BOXL = 196
    END IF
    LOCATE YBOX, XBOX: PRINT CHR$(BOX1); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX2)
    FOR I = 1 TO BOXN
      YBOX = YBOX + 1
      LOCATE YBOX, XBOX: PRINT CHR$(BOXU);
      LOCATE YBOX, XBOX + BOXLEN + 1: PRINT CHR$(BOXU)
    NEXT I
    LOCATE YBOX, XBOX + (BOXLEN - LEN(BOX$)) / 2: PRINT BOX$;
    LOCATE YBOX + 1, XBOX: PRINT CHR$(BOX3); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX4);
    RETURN
'------------------------------------------------------------
```

```
'*********************************************************************
'*...............ADVECTIVE WATER QUALITY MODEL .................*
'*...............Developed by Musa S. Furumele..................*
'*..................OUTPUT HANDLING MODULE.....................*
'*.......................Version 1.0..........................*
'*.......................September 1991........................*
'*********************************************************************
     OPTION BASE 1
     DIM Q1(90, 90), WL1(90, 90), PC1(90, 90), V1(90, 90), LCH(90)
     DIM ITERH(90), ITERP(90), QMAX(90), WMAX(90), QMIN(90)
     DIM WMIN(90), PMAX(90), PMIN(90)
MENU: CLS : COLOR 7, 0
     BOXN = 18: BOXTYPE = 0: YBOX = 3: XBOX = 15: BOXLEN = 50
     BOX$ = "": GOSUB BOX1
     BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
     BOX$ = "ADVETIVE WATER QUALITY MODEL": GOSUB BOX1
     BOXN = 1: BOXTYPE = 1: YBOX = 6: XBOX = 25: BOXLEN = 30
     BOX$ = " OUTPUT OPERATIONS": GOSUB BOX1
     LOCATE 10, 31: PRINT "[ ]..LOAD Output file"
     LOCATE 12, 31: PRINT "[ ]..DISPLAY results "
     LOCATE 14, 31: PRINT "[ ]..PRINT results "
     LOCATE 16, 31: PRINT "[ ]..EXIT Module"
     LOCATE 10, 32: PRINT "L": LOCATE 12, 32: PRINT "D"
     LOCATE 14, 32: PRINT "P": LOCATE 16, 32: PRINT "E"
     COLOR 7, 0: BOXTYPE = 1: YBOX = 18: XBOX = 28: BOXLEN = 25
     BOX$ = " ENTER Selection : [ ]": GOSUB BOX1
     LOCATE 19, 50, 1, 1, 10
100  ED$ = INKEY$: IF ED$ = "" THEN 100
     IF ED$ = "L" OR ED$ = "l" THEN GOSUB LOAD
     IF ED$ = "D" OR ED$ = "d" THEN GOSUB DISP
     IF ED$ = "P" OR ED$ = "p" THEN GOSUB PRNT
     IF ED$ = "E" OR ED$ = "e" THEN CHAIN "DRIVE"
     END
     '------------------------------------------------
DIR1: 'DISPLAY existing Data files
     '-----------------------
     GOSUB CDRV
     CLS : LOCATE 7, 0: PRINT "LIST OF DATA FILES IN DRIVE "; : COLOR
31: PRINT BB$
     COLOR 7, 0: PRINT STRING$(78, 196): ON ERROR GOTO 230
     PRINT "---CROSS-SECTION----": COLOR 7, 0
     EXT = 1: FILES BB$ + "*.CS": ON ERROR GOTO 230
200  PRINT "---BOUNDARY CONDITION----": COLOR 7, 0
     EXT = 2: ON ERROR GOTO 230: FILES BB$ + "*.BC"
     ON ERROR GOTO 0
210  GOSUB DIR2: RETURN
DIR2: LOCATE 23, 28: COLOR 31: PRINT "PRESS ANY KEY TO CONTINUE";
: COLOR 7, 0: BEEP
```

```
220   A$ = INKEY$: IF A$ = "" THEN 220 ELSE RETURN
230   RESUME 240
240   PRINT "No existing files...": BEEP
      ON ERROR GOTO 0: IF EXT = 1 THEN 200 ELSE 210
      RETURN
      '--------------------------
FDOP: 'Filename and Drive Operation
      '--------------------------
      CLS : COLOR 7, 0: BOXN = 1: BOXTYPE = 0: YBOX = 5: XBOX = 16
      BOXLEN = 42: BOX$ = "Insert DATA DISK in DRIVE   " + BB$: GOSUB
BOX1
      LOCATE 10, 26: PRINT "ENTER FILENAME :": COLOR 31
      LOCATE 16, 20: PRINT "Press [Space Bar] to change DRIVE ": COLOR 7, 0
      LOCATE 18, 20: PRINT "    Press [ESC] to abort";
      LL = 0: CY = 10: CX = 43: K$ = F$
      X = 0: F$ = SPACE$(20): WLEN = 8
1100  LOCATE CY, CX + X, 1
1110  A$ = INKEY$: IF A$ = "" OR LEN(A$) = 2 THEN 1100
      K = ASC(A$): IF K = 5 OR K = 12 OR K = 24 THEN 1100
      IF (K = 13 AND X = 0) OR K = 27 THEN F$ = K$: RETURN
      IF A$ <> " " THEN 1120
      IF BB$ = "A:" THEN BB$ = "B:" ELSE IF BB$ = "B:" THEN BB$ = "C:" ELSE
BB$ = "A:"
      COLOR 31: LOCATE 6, 50: PRINT BB$; : COLOR 7, 0: GOTO 1100
1120  IF K = 46 THEN 1110
      IF K = 13 THEN F$ = LEFT$(F$, WLEN): T = 1: RETURN
1130  IF X < 1 AND (K = WLEN) THEN LOCATE CY, CX: PRINT " ": LOCATE
CY, CX: BEEP: GOTO 1100
      IF K = 39 OR K = WLEN THEN A$ = " ": GOTO 1140
      X = X + 1: IF X > WLEN THEN X = WLEN: GOTO 1100
      PRINT A$;
1140  IF X = 0 THEN BEEP: GOTO 1100
      MID$(F$, X, 1) = A$
      IF K = WLEN THEN LOCATE CY, CX + X: PRINT A$: X = X - 1: LOCATE
CY, CX + X: PRINT A$: LOCATE CY, CX + X
      GOTO 1100
      J$ = F$
      CLS : COLOR 7, 0
      RETURN
      '--------------------------
DISP: 'Display results on screen
      '--------------------------
      CLS : COLOR 7, 0: BOXN = 1: BOXTYPE = 0: YBOX = 1: XBOX = 15
      BOXLEN = 50: BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB
BOX1
      BOXN = 1: BOXTYPE = 1: YBOX = 3: XBOX = 20: BOXLEN = 40
      BOX$ = "HYDRODYNAMICS RESULTS": GOSUB BOX1
      FOR I! = 1 TO NCRS: COLOR 7, 0
```

```
      LOCATE 5, 30: PRINT "Cross-section no."; I1
      LOCATE 6, 30: PRINT "-----------------"
      LOCATE 7, 10: PRINT " Time "; SPC(5); "  Flow  "; SPC(7); " Stage "; SPC(7);
"Velocity"; SPC(7); "Iter"
      LOCATE 8, 10: PRINT "(mins)"; SPC(5); "(cumecs)"; SPC(7); "  (m)  "; SPC(7);
" (m/s)  "; SPC(10); "    "
      LOCATE 9, 10: PRINT "--------------------------------------------------------"
      FOR T% = 1 TO NTS
       TM = (T% - 1) * TS
       C = 10
       IF T% > 11 THEN R = T% - 2 ELSE R = T% + 9
       IF T% > 22 THEN
          R = T% - 13
          C = 9
       END IF
       LOCATE R, C: PRINT USING "####.##"; TM; SPC(5); Q1(I1, T%); SPC(7);
WL1(I1, T%); SPC(6); V1(I1, T%); SPC(7); ITERH(T%)
       IF T% = 11 OR T% = 22 THEN
        BOXTYPE = 1: YBOX = 22: XBOX = 26: BOXLEN = 28
        BOX$ = "Press [Enter] to Continue": GOSUB BOX1
        LOCATE 23, 35: INPUT "", ED$: ED$ = INKEY$
        IF ED$ = "E" THEN 1150
       END IF
1150   NEXT T%
      BOXTYPE = 1: YBOX = 22: XBOX = 26: BOXLEN = 28
      BOX$ = "Press [Enter] to Continue": GOSUB BOX1
      LOCATE 23, 35: INPUT "", ED$: ED$ = INKEY$
      IF ED$ = "" THEN 1160
1160   NEXT I1
      GOSUB MENU
      RETURN
      FOR I1 = 1 TO NCRS
       BOXN = 1: BOXTYPE = 0: YBOX = 1: XBOX = 20: BOXLEN = 40
       BOX$ = "ADVETIVE WATER QUALITY MODEL": GOSUB BOX1
       BOXN = 1: BOXTYPE = 1: YBOX = 3: XBOX = 25: BOXLEN = 30
       BOX$ = "POLLUTANT TRANSPORT RESULTS": GOSUB BOX1
       LOCATE 5, 32: PRINT "Cross-section no."; I1
       LOCATE 6, 32: PRINT "-----------------"
       LOCATE 8, 10: PRINT " Time ", "Concentration", "Iter"
       LOCATE 9, 10: PRINT "(mins)", "    (mg/l)    ", ""
       LOCATE 10, 10: PRINT "----------------------------------------"
        FOR T% = 1 TO NTS
         TM = (T% - 1) * TS: R = T% + 10
         LOCATE R, 10: PRINT TM, PC1(I1, T%), SPC(2); , ITERP(T%)
        NEXT T%
      NEXT I1
      RETURN
      '-----------------------
```

```
PRNT: 'Send results to printer
     '--------------------
                    L P R I N T      S P C ( 5 ) ;
"=========================================================="
     LPRINT SPC(5); "ADVECTIVE WATER QUALITY MODEL "
     LPRINT SPC(5); "Developed by Musa S.Furumele"
     LPRINT SPC(5); "Version 1.0"
     LPRINT SPC(5); "September 1991"
                    L P R I N T      S P C ( 5 ) ;
"=========================================================="
     LPRINT SPC(5); "SIMULATION RESULTS  : FILENAME:"; F$
                    L P R I N T      S P C ( 5 ) ;
"*********************************************************"
     LPRINT SPC(5); "Duration         ...="; SD; "mins"
     LPRINT SPC(5); "Time step    (dt)  ="; TS; "mins"
     LPRINT SPC(5); "Reach length (dx)  ="; LC; "m"
     LPRINT SPC(5); "Theta......         ="; TH
     LPRINT SPC(5); "Xi.........        ="; XI
     LPRINT SPC(5); "--------------------------------------------------"
     LPRINT SPC(5); "HYDRODYNAMICS SUB-MODEL"
     LPRINT SPC(5); "-----------------------"
     I1 = 10
     'FOR I1 = 1 TO NCRS
      LPRINT SPC(5); "______________________"
      LPRINT SPC(5); "Cross-section no."; I1 + 1; " at Km"; (I1) * LC
      LPRINT SPC(5); "--------------------"
      LPRINT SPC(5); " Time "; SPC(5); "  Flow  "; SPC(2); " Stage "; SPC(3);
"Velocity"; SPC(5); "Iter"
      LPRINT SPC(5); "(mins)"; SPC(5); "(cumecs)"; SPC(2); "  (m)  "; SPC(3); "
(m/s)  ", "    "
      LPRINT SPC(5); "----------------------------------------------"
      FOR T% = 1 TO NTS
       TIME = (T% - 1) * TS
       IF T% <= 17 THEN
        LPRINT USING "###.##"; SPC(5); TIME; SPC(5); Q1(I1, T%); SPC(5);
WL1(I1, T%); SPC(3); V1(I1, T%); SPC(5); ITERH(T%)
       ELSE
        LPRINT USING "####.##"; SPC(4); TIME; SPC(4); Q1(I1, T%); SPC(4);
WL1(I1, T%); SPC(2); V1(I1, T%); SPC(4); ITERH(T%)
       END IF
      NEXT T%
      LPRINT SPC(5); "______________________________________________"
     'NEXT I1
                    L P R I N T      S P C ( 5 ) ;
"*********************************************************"
      LPRINT SPC(5); "POLLUTANT TRANSPORT SUB-MODEL"
      LPRINT SPC(5); "----------------------------"
     'FOR I1 = 1 TO NCRS
```

```
LPRINT SPC(5); "____________________"
LPRINT SPC(5); "Cross-section no."; I1
LPRINT SPC(5); "-----------------"
LPRINT ""
LPRINT SPC(5); " Time ", "   TDS   ", "Iter"
LPRINT SPC(5); "(mins)", "  (mg/l) ", "    "
LPRINT SPC(5); "-----------------------------"
FOR T% = 1 TO NTS
  TIME = (T% - 1) * TS
  IF T% <= 17 THEN
   LPRINT USING "###.##"; SPC(6); TIME; SPC(4); PC1(I1, T%); SPC(3);
ITERP(T%)
  ELSE
   LPRINT USING "####.##"; SPC(5); TIME; SPC(3); PC1(I1, T%); SPC(2);
ITERP(T%)
  END IF
NEXT T%
LPRINT SPC(5); "-------------------------------------------"
'NEXT I1
                    L P R I N T   S P C ( 5 ) ;
"*****************************************************"
LPRINT SPC(5); "          SUMMARY OF RESULTS          "
LPRINT SPC(5); "Maximum- stage,flow,pollutant concentration"
LPRINT SPC(5); "----------------------------------------"
LPRINT SPC(5); ""
LPRINT SPC(5); "Section", "  Flow  ", " Stage ", " TDS  "
LPRINT SPC(5); "       ", "(cumecs)", "  (m)  ", " mg/l "
LPRINT SPC(5); "----------------------------------------------"
FOR I1 = 1 TO NCRS
 LPRINT USING "###.##"; SPC(5); I1; SPC(4); QMAX(I1); SPC(8);
WMAX(I1); SPC(5); PMAX(I1)
NEXT I1
LPRINT SPC(5); "----------------------------------------------"
LPRINT SPC(5); "Minimum- stage,flow,pollutant concentration"
LPRINT SPC(5); "----------------------------------------"
LPRINT SPC(5); ""
LPRINT SPC(5); "Section", "  Flow  ", " Stage ", " TDS  "
LPRINT SPC(5); "       ", "(cumecs)", "  (m)  ", " mg/l "
LPRINT SPC(5); "----------------------------------------------"
FOR I1 = 1 TO NCRS
 LPRINT USING "###.##"; SPC(5); I1; SPC(4); QMAX(I1); SPC(8);
WMAX(I1); SPC(5); PMAX(I1)
NEXT I1
                    L P R I N T   S P C ( 5 ) ;
"*****************************************************"
RETURN
'-----------------
LOAD:  'LOAD output file
```

```
'------------------
LL = 1: MRG = 0: GOSUB CDRV: CLS : COLOR 7, 0
IF K = 27 THEN IF MRG > 0 THEN MRG = 0
BOXTYPE = 0: YBOX = 1: XBOX = 15: BOXLEN = 40
BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
BOXTYPE = 1: YBOX = 3: XBOX = 1: BOXLEN = 75
BOX$ = "": GOSUB BOX1
X = 0: LOCATE 6, 1, 1, 12, 12: ON ERROR GOTO 1330
FILES BB$ + "*.OUT": PRINT STRING$(77, CHR$(205))
1170   ON ERROR GOTO 0: LOCATE 21, 15: COLOR 31
PRINT " [ESC] to Abort    [ENTER] to Confirm selection";
COLOR 7, 0: K$ = F$: CY = 7: JY = 4: CX = 1: JX = 1
F$ = "": WD = 12: FILE$ = "": TYP = 0
1180  FILE$ = "": FOR Z = 1 TO 12
 FILE$ = FILE$ + CHR$(SCREEN(CY, CX + Z - 1))
NEXT Z
IF FILE$ = "            " THEN CX = JX: CY = JY: FILE$ = F$: GOTO 1200
IF INSTR(FILE$, CHR$(205)) > 0 AND K = 72 THEN BEEP: CY = CY - 1:
GOTO 1320
IF INSTR(FILE$, CHR$(205)) > 0 AND K = 80 THEN 1190 ELSE 1200
1190  BEEP: CY = CY + 1: GOTO 1320
1200  TYP = 0: LOCATE CY, CX: COLOR 0, 7: PRINT FILE$; : COLOR 7, 0
LOCATE 4, 10: PRINT "Loading :"; : COLOR 31
IF INSTR(FILE$, ".OUT") > 0 THEN PRINT "OUTPUT FILES "
LOCATE CY, CX: COLOR 31: PRINT FILE$; : COLOR 7, 0
LOCATE 4, 40: PRINT "Filename: "; : COLOR 0, 7: PRINT FILE$;
1210  COLOR 7, 0: KK$ = INKEY$: IF KK$ = "" THEN 1210
IF LEN(KK$) = 1 THEN K = ASC(KK$) ELSE K = ASC(MID$(KK$, 2, 1))
JY = CY: JX = CX: F$ = FILE$
IF K = 27 THEN 1220 ELSE 1230
1220  IF MRG > 0 THEN MRG = 0
1230  IF K <> 13 THEN 1270
IF MRG <> 3 THEN 1260
1240  MRG = 0: F$ = K$
1250  RESUME 1240
1260  IF MRG = 0 THEN GOTO LO
1270  IF K = 72 OR K = 5 THEN 1280     'UP
IF K = 80 OR K = 24 THEN 1290     'DWN
IF K = 77 OR K = 4 THEN 1300      'RT
IF K = 75 OR K = 19 THEN 1310     'LF
GOTO 1210
1280  IF CY <= 5 THEN 1210 ELSE CY = CY - 1: GOTO 1320
1290  IF CY >= 24 THEN 1210 ELSE CY = CY + 1: GOTO 1320
1300  IF CX >= 66 THEN 1210 ELSE CX = CX + 18: GOTO 1320
1310  IF CX <= 1 THEN 1210 ELSE CX = CX - 18: GOTO 1320
1320  LOCATE JY, JX: PRINT F$: GOTO 1180
1330  RESUME 1340
1340  X = X + 1
```

```
1350   RESUME 1360
1360   IF X = 0 THEN GOSUB 1170 ELSE LOCATE 12, 28: PRINT "No output files
"
       LOCATE 25, 1: PRINT STRING$(40, " "); : BEEP:     GOSUB DIR2
       LOCATE 22, 1: COLOR 7, 0: PRINT STRING$(78, CHR$(196))
LO:    SV = 0: CLS : LOCATE 10, 37: PRINT "LOADING"
       BOXN = 1: BOXTYPE = 0: YBOX = 12: XBOX = 32: BOXLEN = 16
       BOX$ = F$: GOSUB BOX1
       OPEN "I", #1, BB$ + F$ + "OUT"
       INPUT #1, LC
       INPUT #1, NCRS, SD, TS, NTS, TH, XI
       FOR T% = 1 TO NTS
        FOR I1 = 1 TO NCRS
          INPUT #1, Q1(I1, T%), WL1(I1, T%), V1(I1, T%), ITERH(T%)
        NEXT I1
       NEXT T%
       FOR T% = 1 TO NTS
         FOR I1 = 1 TO NCRS
          INPUT #1, PC1(I1, T%), ITERP(T%)
         NEXT I1
       NEXT T%
       FOR I1 = 1 TO NCRS
        INPUT #1, QMAX(I1), QMIN(I1)
        INPUT #1, WMAX(I1), WMIN(I1)
        INPUT #1, PMAX(I1), PMIN(I1)
       NEXT I1
       CLOSE #1
       GOSUB MENU: RETURN
       '--------
BOX1:  'Draws box
       '---------
       COLOR 7, 0
       IF BOXTYPE = 0 THEN BOX1 = 201: BOX2 = 187: BOX3 = 200: BOX4 =
188: BOXU = 186: BOXL = 205
       IF BOXTYPE = 1 THEN BOX1 = 218: BOX2 = 191: BOX3 = 192: BOX4 =
217: BOXU = 179: BOXL = 196
       LOCATE YBOX, XBOX: PRINT CHR$(BOX1); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX2)
       FOR I = 1 TO BOXN
         YBOX = YBOX + 1
         LOCATE YBOX, XBOX: PRINT CHR$(BOXU);
         LOCATE YBOX, XBOX + BOXLEN + 1: PRINT CHR$(BOXU)
       NEXT I
       LOCATE YBOX, XBOX + (BOXLEN - LEN(BOX$)) / 2: PRINT BOX$;
       LOCATE YBOX + 1, XBOX: PRINT CHR$(BOX3); STRING$(BOXLEN,
CHR$(BOXL)); CHR$(BOX4);
       RETURN
       '----------------
```

```
CDRV: 'CHANGE Disk Drive
     '----------------
     CLS ; BOXN = 20: BOXTYPE = 0: YBOX = 3: XBOX = 15
     BOXLEN = 50: BOX$ = "": GOSUB BOX1
     BOXN = 1: BOXTYPE = 0: YBOX = 4: XBOX = 20: BOXLEN = 40
     BOX$ = "ADVECTIVE WATER QUALITY MODEL": GOSUB BOX1
     BOXN = 1: BOXTYPE = 0: YBOX = 6: XBOX = 25: BOXLEN = 30
     BOX$ = "OUTPUT OPERATIONS": GOSUB BOX1
     BOXN = 1: BOXTYPE = 1: YBOX = 10: XBOX = 23: BOXLEN = 34
     BOX$ = "Results will be LOADED from": GOSUB BOX1
     BOXTYPE = 1: YBOX = 14: XBOX = 34: BOXLEN = 12
     BOX$ = "Drive " + BB$: GOSUB BOX1: COLOR 31
     LOCATE 18, 25: PRINT "Press [Space Bar] to change Drive"
     COLOR 7, 0: BOXTYPE = 0: YBOX = 20: XBOX = 25: BOXLEN = 32
     BOX$ = "Press [Enter] to confirm": GOSUB BOX1: GOTO 1390
1370  LOCATE 21, 53
1380  K$ = INKEY$: IF K$ = "" THEN 1380 ELSE K = ASC(K$)
     IF K$ <> " " THEN 1400
     IF BB$ = "A:" THEN BB$ = "B:" ELSE IF BB$ = "B:" THEN BB$ = "C:"
ELSE BB$ = "A:"
1390  LOCATE 15, 44: PRINT BB$; : GOTO 1370
1400  IF K = 13 OR K = 27 THEN RETURN ELSE 1370
     RETURN
```

APPENDIX B

SUMMARY OF RESULTS

```
================================================================
ADVECTIVE WATER QUALITY MODEL
Developed by Musa S.Furumele
Version 1.0
September 1991
================================================================
SIMULATION RESULTS   : FILENAME:RUN3      .OUT
DESCRIPTION : HYPOTHETICAL STUDY
****************************************************************
Duration            ...= 2100 mins
Time step     (dt)  = 60 mins
Reach length  (dx)  = 6000 m
Theta......         = .6
Xi.........         = .5
----------------------------------------------------------------
HYDRODYNAMICS SUB-MODEL
--------------------------------
```

Cross-section no. 1 at Km 0

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.68	3.00	0.42	3.00
60.00	128.87	3.06	0.42	4.00
120.00	141.02	3.23	0.44	4.00
180.00	160.44	3.49	0.46	5.00
240.00	187.33	3.83	0.49	5.00
300.00	218.45	4.20	0.52	5.00
360.00	251.46	4.57	0.55	5.00
420.00	283.41	4.91	0.58	5.00
480.00	308.86	5.17	0.60	5.00
540.00	325.97	5.34	0.61	5.00
600.00	332.10	5.40	0.62	5.00
660.00	325.97	5.34	0.61	5.00
720.00	308.86	5.17	0.60	5.00
780.00	283.41	4.91	0.58	5.00
840.00	251.46	4.57	0.55	5.00
900.00	218.45	4.20	0.52	4.00
960.00	187.33	3.83	0.49	4.00
1020.00	160.44	3.49	0.46	4.00
1080.00	141.02	3.23	0.44	4.00
1140.00	128.87	3.06	0.42	4.00
1200.00	124.68	3.00	0.42	3.00
1260.00	124.68	3.00	0.42	3.00
1320.00	124.68	3.00	0.42	4.00
1380.00	124.68	3.00	0.42	4.00
1440.00	124.68	3.00	0.42	4.00
1500.00	124.68	3.00	0.42	4.00
1560.00	124.68	3.00	0.42	4.00

1620.00	124.68	3.00	0.42	4.00
1680.00	124.68	3.00	0.42	4.00
1740.00	124.68	3.00	0.42	4.00
1800.00	124.68	3.00	0.42	4.00
1860.00	124.68	3.00	0.42	4.00
1920.00	124.68	3.00	0.42	4.00
1980.00	124.68	3.00	0.42	4.00
2040.00	124.68	3.00	0.42	4.00
2100.00	124.68	3.00	0.42	4.00

Cross-section no. 9 at Km 48

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.99	3.00	0.42	3.00
60.00	125.00	3.00	0.42	4.00
120.00	125.27	3.01	0.42	4.00
180.00	126.64	3.03	0.42	5.00
240.00	129.17	3.06	0.42	5.00
300.00	133.49	3.13	0.43	5.00
360.00	140.35	3.22	0.44	5.00
420.00	150.54	3.36	0.45	5.00
480.00	164.66	3.54	0.46	5.00
540.00	182.68	3.77	0.48	5.00
600.00	203.31	4.03	0.51	5.00
660.00	225.49	4.28	0.53	5.00
720.00	245.59	4.51	0.55	5.00
780.00	261.87	4.68	0.56	5.00
840.00	273.24	4.80	0.57	5.00
900.00	279.39	4.87	0.57	4.00
960.00	280.58	4.88	0.58	4.00
1020.00	278.29	4.86	0.57	4.00
1080.00	274.05	4.81	0.57	4.00
1140.00	268.57	4.75	0.57	4.00
1200.00	261.65	4.68	0.56	3.00
1260.00	253.11	4.59	0.55	3.00
1320.00	243.59	4.48	0.54	4.00
1380.00	234.23	4.38	0.53	4.00
1440.00	224.24	4.27	0.53	4.00
1500.00	213.09	4.14	0.52	4.00
1560.00	202.49	4.01	0.50	4.00
1620.00	192.56	3.89	0.49	4.00
1680.00	183.16	3.78	0.48	4.00
1740.00	174.57	3.67	0.48	4.00
1800.00	166.68	3.57	0.47	4.00
1860.00	159.60	3.48	0.46	4.00
1920.00	153.38	3.40	0.45	4.00
1980.00	148.05	3.33	0.45	4.00
2040.00	143.59	3.27	0.44	4.00
2100.00	140.09	3.22	0.44	4.00

```
==============================================
ADVECTIVE WATER QUALITY MODEL
Developed by Musa S.Pazamela
Version 1.0
September 1991
==============================================
SIMULATION RESULTS  : FILENAME:RUN4    .OUT
DESCRIPTION : HYPOTHETICAL STUDY
**********************************************
Duration          ...= 2100 mins
Time step    (dt)  = 60 mins
Reach length (dx)  = 1000 m
Theta......        = 1
Xi.........        = .5
----------------------------------------------
HYDRODYNAMICS SUB-MODEL
-----------------------

Cross-section no. 1  at Km 0
```

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.68	3.00	0.42	3.00
60.00	128.87	3.06	0.42	4.00
120.00	141.02	3.23	0.44	4.00
180.00	160.44	3.49	0.46	5.00
240.00	187.33	3.83	0.49	5.00
300.00	218.45	4.20	0.52	5.00
360.00	251.46	4.57	0.55	5.00
420.00	283.41	4.91	0.58	5.00
480.00	308.86	5.17	0.60	5.00
540.00	325.97	5.34	0.61	5.00
600.00	332.10	5.40	0.62	5.00
660.00	325.97	5.34	0.61	5.00
720.00	308.86	5.17	0.60	5.00
780.00	283.41	4.91	0.58	5.00
840.00	251.46	4.57	0.55	5.00
900.00	218.45	4.20	0.52	5.00
960.00	187.33	3.83	0.49	4.00
1020.00	160.44	3.49	0.46	4.00
1080.00	141.02	3.23	0.44	4.00
1140.00	128.87	3.06	0.42	4.00
1200.00	124.68	3.00	0.42	4.00
1260.00	124.68	3.00	0.42	4.00
1320.00	124.68	3.00	0.42	4.00
1380.00	124.68	3.00	0.42	4.00
1440.00	124.68	3.00	0.42	4.00
1500.00	124.68	3.00	0.42	4.00
1560.00	124.68	3.00	0.42	4.00
1620.00	124.68	3.00	0.42	4.00
1680.00	124.68	3.00	0.42	4.00
1740.00	124.68	3.00	0.42	4.00

1800.00	124.68	3.00	0.42	4.00
1860.00	124.68	3.00	0.42	4.00
1920.00	124.68	3.00	0.42	4.00
1980.00	124.68	3.00	0.42	4.00
2040.00	124.68	3.00	0.42	4.00
2100.00	124.68	3.00	0.42	4.00

Cross section no. 4[illegible] at Km 4[illegible]

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	T[illegible]
0.00	124.96	3.00	0.42	3.00
60.00	125.10	3.01	0.42	4.00
120.00	125.87	3.02	0.42	4.00
180.00	127.59	3.04	0.42	5.00
240.00	130.76	3.09	0.42	5.00
300.00	135.93	3.16	0.43	5.00
360.00	1[illegible]5.69	3.27	0.44	5.00
420.00	154.66	3.41	0.45	5.00
480.00	168.89	3.60	0.47	5.00
540.00	186.29	3.82	0.49	5.00
600.00	205.67	4.05	0.51	5.00
660.00	225.31	4.28	0.53	5.00
720.00	243.26	4.48	0.54	5.00
780.00	257.78	4.64	0.56	5.00
840.00	[illegible]	4.75	0.56	5.00
900.00	273.55	4.81	0.57	5.00
960.00	274.70	4.82	0.57	4.00
1020.00	272.96	4.80	0.57	4.00
1080.00	269.44	4.76	0.57	4.00
1140.00	264.69	4.71	0.56	4.00
1200.00	255.22	4.64	0.56	4.00
1260.00	250.26	4.56	0.55	4.00
1320.00	241.59	4.46	0.54	4.00
1380.00	233.22	4.37	0.53	4.00
1440.00	222.84	4.25	0.52	4.00
1500.00	212.31	4.13	0.51	4.00
1560.00	202.07	4.01	0.50	4.00
1620.00	192.24	3.89	0.49	4.00
1680.00	183.01	3.78	0.48	4.00
1740.00	174.46	3.67	0.48	4.00
1800.00	166.62	3.57	0.47	4.00
1860.00	159.65	3.48	0.46	4.00
1920.00	153.55	3.40	0.45	4.00
1980.00	148.35	3.33	0.45	4.00
2040.00	144.14	3.27	0.44	4.00
2100.00	140.81	3.23	0.44	4.00

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.68	3.00	0.42	3.00
120.00	141.02	3.23	0.44	5.00
240.00	187.33	3.83	0.49	6.00
360.00	251.46	4.57	0.57	7.00
480.00	308.86	5.17	0.60	6.00
600.00	332.10	5.40	0.62	6.00
720.00	308.56	5.17	0.60	6.00
840.00	251.46	4.57	0.55	5.00
960.00	187.23	3.83	0.49	5.00
1080.00	141.02	3.23	0.44	4.00
1200.00	124.68	3.00	0.42	4.00
1320.00	124.68	3.00	0.42	4.00
1440.00	124.68	3.00	0.42	4.00
1560.00	124.68	3.00	0.42	4.00
1680.00	124.68	3.00	0.42	4.00
1800.00	124.68	3.00	0.42	4.00
1920.00	124.68	3.00	0.42	4.00
2040.00	124.68	3.00	0.42	4.00

```
=============================================================
ADVECTIVE WATER QUALITY MODEL
Developed by Musa S.Furumele
Version 1.0
September 1991
=============================================================
SIMULATION RESULTS  :  FILENAME:RUN6      .OUT
DESCRIPTION : HYPOTHETICAL STUDY
*************************************************************
Duration              = [illegible] mins
Time step     (dt)    = 120 mins
Reach length (dx)     = 6000 m
Theta......           = .6
Zi.........           = .5
-------------------------------------------------------------
HYDRODYNAMICS SUB-MODEL
------------------------
```

Cross-section no. 9 at Km 48

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.96	3.00	0.42	3.00
120.00	125.68	3.01	0.42	5.00
240.00	129.91	3.07	0.42	6.00
360.00	142.20	3.25	0.44	7.00
480.00	167.66	3.58	0.47	6.00
600.00	206.43	4.06	0.51	6.00
720.00	246.36	4.41	0.55	6.00
840.00	272.49	4.71	0.57	5.00
960.00	279.67	4.78	0.57	5.00
1080.00	273.91	4.72	0.57	4.00
1200.00	261.71	4.59	0.56	4.00
1320.00	244.28	4.49	0.54	4.00
1440.00	223.68	4.26	0.53	4.00
1560.00	202.72	4.02	0.50	4.00
1680.00	183.46	3.78	0.49	4.00
1800.00	166.99	3.57	0.47	4.00
1920.00	153.76	3.40	0.45	4.00
2040.00	144.03	3.27	0.44	4.00

****

POLLUTANT TRANSPORT SUB-MODEL

ADVECTIVE WATER QUALITY MODEL
Developed by Musa S.Furumele
Version 1.0
September 1991

SIMULATION RESULTS : FILENAME:RUN7 .OUT
DESCRIPTION : HYPOTHETICAL STUDY

Duration ...= 2100 mins
Time step (dt) = 60 mins
Reach length (dx) = 12000 m
Theta...... = .6
Xi......... = .5

HYDRODYNAMICS SUB-MODEL

Cross-section no. at Km-

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.68	3.00	0.42	3.00
60.00	128.87	3.06	0.42	4.00
120.00	141.02	3.23	0.44	4.00
180.00	160.44	3.49	0.46	5.00
240.00	187.33	3.83	0.49	5.00
300.00	218.45	4.20	0.52	5.00
360.00	251.46	4.57	0.55	5.00
420.00	283.41	4.91	0.58	5.00
480.00	308.86	5.17	0.60	5.00
540.00	325.97	5.34	0.61	5.00
600.00	332.10	5.40	0.62	5.00
660.00	325.97	5.34	0.61	5.00
720.00	308.86	5.17	0.60	5.00
780.00	283.41	4.91	0.58	5.00
840.00	251.46	4.57	0.55	4.00
900.00	218.45	4.20	0.52	4.00
960.00	187.33	3.83	0.49	4.00
1020.00	160.44	3.49	0.46	4.00
1080.00	141.02	3.23	0.44	4.00
1140.00	128.87	3.06	0.42	4.00
1200.00	124.68	3.00	0.42	3.00
1260.00	124.68	3.00	0.42	3.00
1320.00	124.68	3.00	0.42	4.00
1380.00	124.68	3.00	0.42	4.00
1440.00	124.68	3.00	0.42	4.00
1500.00	124.68	3.00	0.42	4.00
1560.00	124.68	3.00	0.42	4.00

1620.00	124.68	3.00	0.42	4.00
1680.00	124.68	3.00	0.42	4.00
1740.00	124.68	3.00	0.42	4.00
1800.00	124.68	3.00	0.42	4.00
1860.00	124.68	3.00	0.42	4.00
1920.00	124.68	3.00	0.42	4.00
1980.00	124.68	3.00	0.42	4.00
2040.00	124.68	3.00	0.42	4.00
2100.00	124.68	3.00	0.42	4.00

Cross-section no. 5 at Km 48

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.68	3.00	0.42	3.00
60.00	126.07	3.02	0.42	4.00
120.00	130.98	3.09	0.42	4.00
180.00	138.12	3.19	0.43	5.00
240.00	148.37	3.33	0.45	5.00
300.00	161.21	3.50	0.46	5.00
360.00	176.06	3.69	0.48	5.00
420.00	193.07	3.90	0.50	5.00
480.00	209.85	4.10	0.51	5.00
540.00	228.07	4.31	0.53	5.00
600.00	245.07	4.50	0.54	5.00
660.00	260.70	4.67	0.56	5.00
720.00	273.85	4.81	0.57	5.00
780.00	283.41	4.91	0.58	5.00
840.00	290.17	4.98	0.58	4.00
900.00	292.12	5.10	0.58	4.00
960.00	291.15	4.99	0.58	4.00
1020.00	290.17	4.98	0.58	4.00
1080.00	289.20	4.97	0.58	4.00
1140.00	287.27	4.95	0.58	4.00
1200.00	280.53	4.88	0.57	3.00
1260.00	271.01	4.78	0.57	3.00
1320.00	259.77	4.66	0.56	4.00
1380.00	251.46	4.57	0.55	4.00
1440.00	231.61	4.35	0.53	4.00
1500.00	215.86	4.17	0.52	4.00
1560.00	200.55	3.99	0.50	4.00
1620.00	185.70	3.81	0.49	4.00
1680.00	172.10	3.64	0.47	4.00
1740.00	159.68	3.48	0.46	4.00
1800.00	148.37	3.33	0.45	4.00
1860.00	139.57	3.21	0.43	4.00
1920.00	132.40	3.11	0.43	4.00
1980.00	127.47	3.04	0.42	4.00
2040.00	125.38	3.01	0.42	4.00
2100.00	124.68	3.00	0.42	4.00

ADVECTIVE WATER QUALITY MODEL
Developed by Musa S.Farumele
Version 1.0
September 1991

SIMULATION RESULTS : FILENAME:RUN8 .OUT
DESCRIPTION ; HYPOTHETICAL STUDY

Duration ...= 2100 mins
Time step (dt) = 60 mins
Reach length (dx) = [illegible]
Theta...... = .6
Xi......... = .5

HYDRODYNAMICS SUB-MODEL

Cross-section no. 1 at Km 0

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.68	3.00	0.42	3.00
60.00	128.87	3.06	0.42	4.00
120.00	141.02	3.23	0.44	4.00
180.00	160.44	3.49	0.46	5.00
240.00	187.33	3.83	0.49	5.00
300.00	218.45	4.20	0.52	5.00
360.00	251.46	4.57	0.55	5.00
420.00	283.41	4.91	0.58	5.00
480.00	308.86	5.17	0.60	5.00
540.00	325.97	5.34	0.61	5.00
600.00	332.10	5.40	0.62	5.00
660.00	325.97	5.34	0.61	5.00
720.00	308.86	5.17	0.60	5.00
780.00	283.41	4.91	0.58	5.00
840.00	251.46	4.57	0.55	5.00
900.00	218.45	4.20	0.52	4.00
960.00	187.33	3.83	0.49	4.00
1020.00	160.44	3.49	0.46	4.00
1080.00	141.02	3.23	0.44	4.00
1140.00	128.87	3.06	0.42	4.00
1200.00	124.68	3.00	0.42	3.00
1260.00	124.68	3.00	0.42	3.00
1320.00	124.68	3.00	0.42	4.00
1380.00	124.68	3.00	0.42	4.00
1440.00	124.68	3.00	0.42	4.00
1500.00	124.68	3.00	0.42	4.00
1560.00	124.68	3.00	0.42	4.00
1620.00	124.68	3.00	0.42	4.00
1680.00	124.68	3.00	0.42	4.00
1740.00	124.68	3.00	0.42	4.00

1800.00	124.68	3.00	0.42	4.00
1860.00	124.68	3.00	0.42	4.00
1920.00	124.68	3.00	0.42	4.00
1980.00	124.68	3.00	0.42	4.00
2040.00	124.68	3.00	0.42	4.00
2100.00	124.68	3.00	0.42	4.00

Cross-section no. 49 at Km 48

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	124.99	3.00	0.42	3.00
60.00	125.03	3.00	0.42	[illegible].00
120.00	125.55	3.01	0.42	4.00
180.00	126.95	3.03	0.42	5.00
240.00	129.61	3.07	0.42	5.00
300.00	134.06	3.12	0.43	5.00
360.00	140.98	3.23	0.44	5.00
420.00	151.12	3.37	0.45	5.00
480.00	165.03	3.55	0.47	5.00
540.00	182.79	3.77	0.48	5.00
600.00	203.51	4.03	0.51	5.00
660.00	225.08	4.28	0.53	5.00
720.00	245.07	4.50	0.54	5.00
780.00	261.32	4.68	0.56	5.00
840.00	272.72	4.80	0.57	5.00
900.00	278.87	4.86	0.57	4.00
960.00	280.10	4.88	0.57	4.00
1020.00	277.90	4.85	0.57	4.00
1080.00	273.73	4.81	0.57	4.00
1140.00	268.30	4.75	0.56	4.00
1200.00	261.38	4.68	0.56	3.00
1260.00	252.88	4.59	0.55	3.00
1320.00	243.43	4.48	0.54	4.00
1380.00	234.21	4.38	0.53	4.00
1440.00	224.03	4.26	0.53	4.00
1500.00	212.93	4.14	0.51	4.00
1560.00	202.32	4.01	0.50	4.00
1620.00	192.32	3.89	0.49	4.00
1680.00	182.91	3.78	0.48	4.00
1740.00	174.24	3.67	0.48	4.00
1800.00	166.31	3.57	0.47	4.00
1860.00	159.20	3.47	0.46	4.00
1920.00	153.00	3.39	0.45	4.00
1980.00	147.69	3.32	0.44	4.00
2040.00	143.34	3.26	0.44	4.00
2100.00	139.93	3.22	0.44	4.00

ADVECTIVE WATER QUALITY MODEL
Developed by Musa S. Furamele
Version 1.0
September 1991

SIMULATION RESULTS : FILENAME: KLIPM .OUT
DESCRIPTION : KLIP RIVER-JULY1978

Duration ...= 1440 mins
Time step (dt) = 60 mins
Reach length (dx) = 540 m
Theta...... = .6
Xi......... = .5

HYDRODYNAMICS SUB-MODEL

Cross-section no. 1 at Km 0

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	3.40	0.89	0.29	1.00
60.00	3.40	0.89	0.29	1.00
120.00	3.40	0.89	0.29	1.00
180.00	3.40	0.89	0.29	1.00
240.00	3.40	0.89	0.29	1.00
300.00	3.40	0.89	0.29	1.00
360.00	3.40	0.89	0.29	1.00
420.00	3.40	0.89	0.29	1.00
480.00	3.40	0.89	0.29	1.00
540.00	3.40	0.89	0.29	1.00
600.00	3.40	0.89	0.29	1.00
660.00	3.40	0.89	0.29	1.00
720.00	3.40	0.89	0.29	1.00
780.00	3.40	0.89	0.29	1.00
840.00	3.40	0.89	0.29	1.00
900.00	3.40	0.89	0.29	1.00
960.00	3.40	0.89	0.29	1.00
1020.00	3.40	0.89	0.29	1.00
1080.00	3.40	0.89	0.29	1.00
1140.00	3.40	0.89	0.29	1.00
1200.00	3.40	0.89	0.29	1.00
1260.00	3.40	0.89	0.29	1.00
1320.00	3.40	0.89	0.29	1.00
1380.00	3.40	0.89	0.29	1.00
1440.00	3.40	0.89	0.29	1.00

Cross-section no. 11 at Km 5.4

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	3.41	0.90	0.29	1.00
60.00	3.41	0.90	0.29	1.00
120.00	3.41	0.90	0.29	1.00
180.00	3.41	0.89	0.29	1.00
240.00	3.41	0.89	0.29	1.00
300.00	3.41	0.89	0.29	1.00
360.00	3.41	0.89	0.29	1.00
420.00	3.41	0.89	0.29	1.00
480.00	3.40	0.89	0.29	1.00
540.00	3.40	0.89	0.29	1.00
600.00	3.40	0.89	0.29	1.00
660.00	3.40	0.89	0.29	1.00
720.00	3.40	0.89	0.29	1.00
780.00	3.40	0.89	0.29	1.00
840.00	3.40	0.89	0.29	1.00
900.00	3.40	0.89	0.29	1.00
960.00	3.40	0.89	0.29	1.00
1020.00	3.40	0.89	0.29	1.00
1080.00	3.40	0.89	0.29	1.00
1140.00	3.40	0.89	0.29	1.00
1200.00	3.40	0.89	0.29	1.00
1260.00	3.40	0.89	0.29	1.00
1320.00	3.40	0.89	0.29	1.00
1380.00	3.40	0.89	0.29	1.00
1440.00	3.40	0.89	0.29	1.00

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POLLUTANT TRANSPORT SUB-MODEL

Cross-section no. 1

Time (mins)	TDS (mg/l)	Iter
0.00	960.15	2.00
60.00	973.79	2.00
120.00	984.67	2.00
180.00	991.19	2.00
240.00	981.87	2.00
300.00	981.87	2.00
360.00	987.04	2.00
420.00	988.05	2.00
480.00	998.04	2.00

540.00	%1002.09	2.00
600.00	%1002.09	2.00
660.00	998.04	2.00
720.00	998.04	2.00
780.00	984.07	2.00
840.00	994.00	2.00
900.00	997.70	2.00
960.00	989.96	2.00
1020.00	998.04	2.00
1080.00	998.04	2.00
1140.00	980.08	2.00
1200.00	980.06	2.00
1260.00	983.03	2.00
1320.00	989.95	2.00
1380.00	985.91	2.00
1440.00	985.91	2.00

Cross-section no. 11

Time (mins)	TDS (mg/l)	Iter
0.00	960.79	2.00
60.00	961.50	2.00
120.00	961.50	2.00
180.00	961.80	2.00
240.00	967.50	2.00
300.00	971.96	2.00
360.00	976.60	2.00
420.00	979.60	2.00
480.00	982.40	2.00
540.00	985.10	2.00
600.00	988.00	2.00
660.00	991.10	2.00
720.00	993.89	2.00
780.00	995.80	2.00
840.00	996.40	2.00
900.00	996.00	2.00
960.00	995.20	2.00
1020.00	994.50	2.00
1080.00	994.20	2.00
1140.00	994.00	2.00
1200.00	983.32	2.00
1260.00	992.00	2.00
1320.00	989.00	2.00
1380.00	988.14	2.00
1440.00	982.54	2.00

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ADVECTIVE WATER QUALITY MODEL
Developed by Musa S.Furumele
Version 1.0
September 1991
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SIMULATION RESULTS   : FILENAME:KLIP3     .OUT
DESCRIPTION : KLIP RIVER-MARCH 1979
***************************************************************************
Duration            ...= 360 mins
Time step     (dt)   = 60 mins
Reach length (dx)    = 540 m
Theta......          = .6
Xi.........          = .5
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HYDRODYNAMICS SUB-MODEL
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Cross-section no. 1 at Km 0

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	4.20	102.00	0.30	1.00
60.00	4.20	102.00	0.30	1.00
120.00	4.20	102.00	0.30	1.00
180.00	4.20	102.00	0.30	1.00
240.00	4.20	102.00	0.30	1.00
300.00	4.20	102.00	0.30	1.00
360.00	4.20	102.00	0.30	1.00

Cross-section no. 6 at Km 2.7

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	4.20	101.50	0.30	1.00
60.00	4.20	101.50	0.30	1.00
120.00	4.20	101.50	0.30	1.00
180.00	4.20	101.50	0.30	1.00
240.00	4.20	101.50	0.30	1.00
300.00	4.20	101.50	0.30	1.00
360.00	4.20	101.50	0.30	1.00

Cross-section no. 11 at Km 5.4

Time (mins)	Flow (cumecs)	Stage (m)	Velocity (m/s)	Iter
0.00	4.20	101.00	0.30	1.00
60.00	4.20	101.00	0.30	1.00
120.00	4.20	101.00	0.30	1.00
180.00	4.20	101.00	0.30	1.00
240.00	4.20	101.00	0.30	1.00
300.00	4.20	101.00	0.30	1.00
360.00	4.20	101.00	0.30	1.00

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POLLUTANT TRANSPORT SUB-MODEL

Cross-section no. 1

Time (mins)	TDS (mg/l)	Iter
0.00	%1241.65	1.00
60.00	%1241.40	2.00
120.00	%1241.30	2.00
180.00	%1263.24	2.00
240.00	%1278.83	2.00
300.00	%1251.03	2.00
360.00	%1382.44	2.00

Cross-section no. 6

Time (mins)	TDS (mg/l)	Iter
0.00	%1241.56	1.00
60.00	%1241.20	2.00
120.00	%1241.00	2.00
180.00	%1256.49	2.00
240.00	%1249.35	2.00
300.00	%1242.38	2.00
360.00	%1277.44	2.00

Cross-section no. 11

Time (mins)	TDS (mg/1)	Iter
0.00	%1241.20	1.00
60.00	%1241.35	2.00
120.00	%1240.84	2.00
180.00	%1239.06	2.00
240.00	%1234.56	2.00
300.00	%1226.58	2.00
360.00	%1217.97	2.00

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