Water resource system training model "WATSYS"

User's manual

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FOREWORD

The manual of the WATer resources SYStem program presented in this issue of
the Reports of our department completes the first phase of the development
of a computer-based training model. It has been conceived to enable
students and trainees of water resources engineering, hydrology and related
fields to study and to test streamflow patterns of surface water resources
systems.
Open channel flow may change due to variation of hydrological parameters
controlling the physical state of a catchment, and subsequently rainfall-
runoff relationship.
Discharges are also influenced by the existence of flood control and
conservation storage reservoirs, as well as by their operational policies.
By focusing only on a few, yet significant components of a river basin
system, WATSYS has explicitly been kept as simple as possible. Thus it is
hoped to facilitate the first steps of its users into the fascinating world
of water resources system modeling.
WATSYS is a training model in double sense. To be a training tool is not
only the purpose of this software, but most of its development was training
itself. The two core elements, the internationally well known Nedbor-
Afstromings-Model (NAM) rainfall runoff model and the reservoir and river
routing subroutines (BAME) have been developed at the Technical University
of Denmark and at the University of Karlsruhe, Germany. Both Steen Asger
Nielsen and myself have been involved at those initial stages back in the
seventies while working for our respective academic degrees.
The idea to couple these two components into a training model emerged in
1987 while serving together as faculty members of the Division of Water
Resources Engineering at the Asian Institute of Technology (AIT) in
Bangkok, Thailand.
Mr. Wang Jian-Chyun, a graduate student from Taiwan, R.O.C. deserves the
merit for setting up the first version of this joint hydrological and water
resources management model. The second version of what was to be called
WATSYS has been a step towards "user friendliness". It has been the
contribution of Mr. Bijaya Prakash Shrestha M.Eng. from Nepal. This work
was also carried out at AIT.
The present version has been worked out by Bart A.H.V. Brorens within the
framework of a thesis towards his Ir.-qualification at the Wageningen
Agricultural University. He did not only subject himself to the rigorous
exercise to think once more the thoughts of his predecessors, but compiled
this User's Manual, the basic tool needed to release WATSYS to serve the
educational purpose it was originally conceived for.
For the sake of demonstration the rainfall and runoff data collected during
the 1978 May and June floods in the Sulm Creek catchment in Southwestern
Germany have been incorporated. In this respect thanks are due to the Water
Resources Management Authorities of the Land Baden-Württemberg and
especially to Mr. Heinz Daucher for their kind cooperation.
The Wageningen Agricultural University claims to be an international
university. I am therefore very pleased to present the WATSYS model and its
manual as the result of a truly international cooperation, a work of
dedicated students for the benefit of their fellow students interested in
water resources management.

Prof.Dr.-Ing. Janos J. Bogardi

CONTENTS

1.   INTRODUCTION

WATSYS is a MS-DOS computer based modelling system for surface water systems management. It is a coupling of two models:
A precipitation runoff model (NAM) and a river network simulation model (BAME).

NAM is an abbreviation of the Danish "Nedbor-Afstromnings-model", meaning precipitation runoff model. This model has been developed by the Hydrological Section of the Institute of Hydrodynamics and Hydraulic Engineering at the Technical University of Denmark. It describes in a simplified quantitative form the behaviour of the land phase of the hydrological cycle.

The river network simulation model, BAME, has been developed by J. Bogardi at the University of Karlsruhe, Germany.
It is a hydrologic river and reservoir routing simulation model, based on the linear reservoir routing.
The models were coupled at the Asian Institute of Technology.

WATSYS is mainly developed for didactic purposes. The user can observe the responses of a water resources system due to different hydrological inputs and management policies: The precipitation, evapotranspiration, incoming inflows, different model parameters, routing methods and different reservoir operation rules. Thus this training model is intended to enhance the analytical capabilities of trainees by allowing them to gain insight into hydrological phenomena and consequences of water resources management decisions.

Hardware and Software

The WATSYS model is a training model and therefore primarily will be used by students during classes. Three versions of WATSYS were compiled to guaranty the model to run on a great variety of personal computers: A version which runs on MS-DOS-XT (8086) machines, a version for an MS-DOS-AT (80286 or 80386) and a version which requires an MS-DOS-AT (80286 or 80386) with mathematical coprocessor (80287 or resp. 80387). The versions are called respectively WATSYSXT, WATSYSAT and WATSYS87.
The first version is the slowest, but it may be used on all three the computers, the last is the fastest, but can only be used on PC's having the required features.

A VGA colour display will enhance the screens of WATSYS but is not necessary for running WATSYS. A CGA, EGA, or VGA display or a display which supports simulating CGA (for example with the program SIMCGA.COM) is necessary for using the hydrograph facility.

Installing WATSYS

On your WATSYS diskette(s) you find in the root directory the WATSYS
execute files (extension .EXE), for each above mentioned version. Copy the
correct version to your hard disk, for example to the directory C:\WATSYS\
(replace "??" with "XT", "AT" or "87", corresponding with the version you
want to install):

        XCOPY A:\WATSYS??.EXE C:\WATSYS*.*

Your diskette contains two subdirectories containing the models display
files (extension .DIS). If you use a colour display you should copy the
files in the subdirectory COLOUR\ to your WATSYS\ directory, if you use a
monochrome display, you use the files in the directory MONOCHRM\.

        XCOPY A:\COLOUR*.* C:\WATSYS*.* or:

        XCOPY A:\MONOCHRM*.* C:\WATSYS*.*

As WATSYS uses ANSI escape sequences (for more information: see your DOS-
manual) you have to install the ANSI.SYS device driver or make sure that it
already has been installed. You install the driver by putting

        DEVICE=ANSI.SYS

in your CONFIG.SYS file and then reboot (this means restart) your machine.
In this example the ANSI.SYS file has to be in the root directory. As the
ANSI.SYS file is an MS-DOS file, you usually will find it in your DOS
directory, e.g. C:\DOS\.
In that case you have to type

        DEVICE=C:\DOS\ANSI.SYS

in your CONFIG.SYS file, followed by rebooting the computer.

To start WATSYS go to your WATSYS directory and type the name of the
version of WATSYS you want to use:

    CD\
    CD WATSYS
    WATSYSXT, WATSYSAT or WATSYS87

In the directory TESTSET\ you find an example of WATSYS input files. See
Appendix IV for more information. Copy these files to your directory by:

        XCOPY A:\TESTSET*.* C:\WATSYS*.*

2   THE MODELS IN WATSYS: NAM AND BAME

The WATSYS model is the result of a coupling of a precipitation runoff
model (NAM) and a river network simulation model (BAME). They are coupled
by using the output of the first model, outflow at the outlet of
subcatchments, as input for the second model. Both the models and their
coupling is dealt with in this chapter. Section 2.1 is taken from the "NAM
model documentation" of the Danish Hydraulic Institute.

2.1   The NAM precipitation runoff model

The NAM precipitation runoff model is a so-called deterministic,
conceptual, lumped model. Being a lumped model, NAM subdivides a catchment
into uniform sub-units (subcatchments). Parameters and variables represent
average values for a subcatchment. Being deterministic NAM requires the
input time series of precipitation, potential evapotranspiration and
temperature (optional) to be known in advance.
A conceptual model like NAM is based on physical structures and equations
used together with semi-empirical ones. Thus, some of the parameters can be
evaluated from physical data, but the final parameter estimation must be
performed by calibration applying concurrent input and output time series.

NAM simulates the precipitation-runoff process in rural catchments. It
operates by continuously accounting for the moisture content in five
different and mutually interrelated storages which represent physical
elements of the catchment.

The input data to the model are: Precipitation, potential
evapotranspiration, and temperature (for the snow routine). On this basis,
it produces mean daily values of stream flow. This stream flow is then
used as inflow for the BAME model.

The NAM model structure
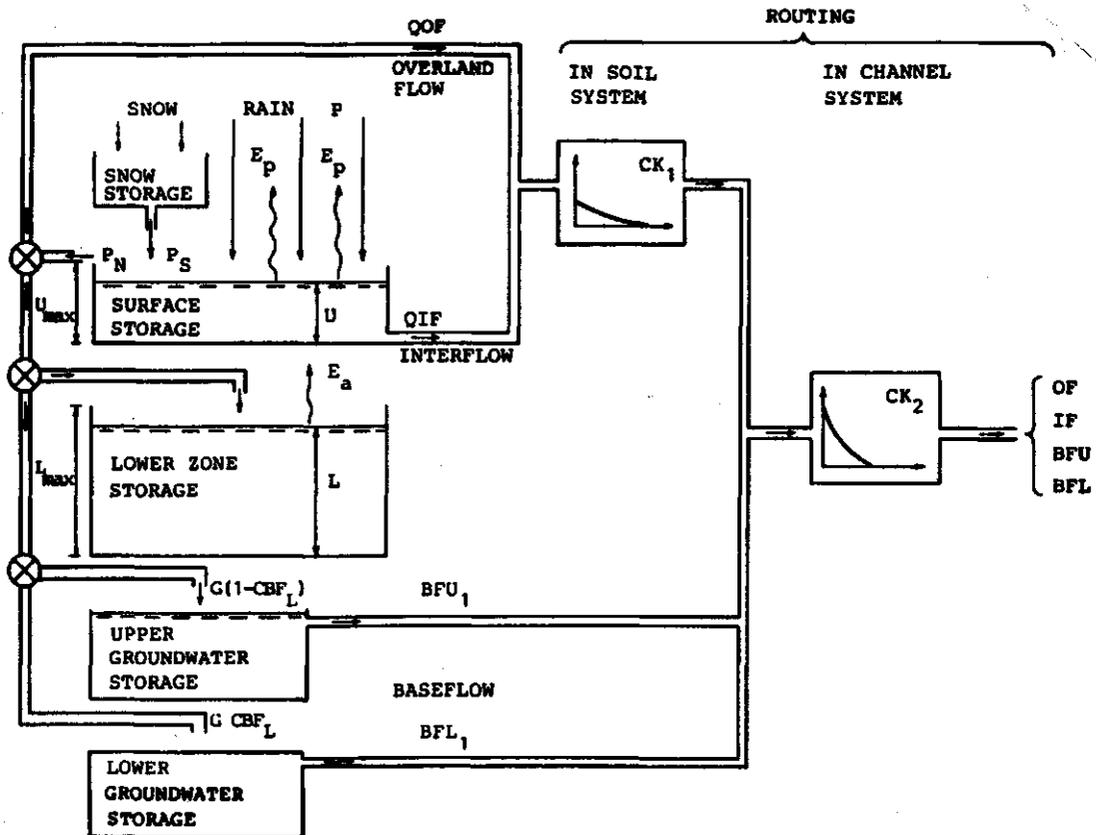
Figure 2.1 Structure of the NAM model.

Figure 2.1 shows the model structure. It is an attempt to make a simplified imitation of the land phase of the hydrological cycle.

1.   Precipitation passing through the snow storage is controlled by temperature conditions.

2.   Moisture intercepted on the vegetation, as well as water trapped in depressions and in the uppermost part of the cultivated part of the ground is intercepted as surface storage. U_{MAX} (see figure 2.1) denotes the upper limit to the amount of water in surface storage.

3.   The soil moisture in the root zone, a soil layer below the surface from which the vegetation can draw water for transpiration, is represented as lower zone storage. L_{MAX} denotes an upper limit to the amount of water in this storage.

4.   Rain and melted snow are subject, first, to the functions of the surface storage. The amount of water, U, in surface storage is continuously diminished by evaporative consumption as well as by horizontal leakage (interflow). When there is maximum surface storage, some of the excess water will enter the stream as overland flow, whereas the remainder is diverted as infiltration into lower zone and groundwater storages.

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5.   The groundwater recharge is generally divided into two groundwater storages, upper and lower, having different time constants. The groundwater storages act as linear reservoirs continuously draining to the stream base flow.

6.   The overland flow and the interflow are routed through one linear reservoir before all of the stream flow components are added and routed through a final linear reservoir; thus, a continuous stream flow hydrograph can be obtained. (This stream flow is used subsequently as input for the BAME model.)

The Quantitative Relations

The quantitative relations governing the processes of the interrelationship between the various storages are described below.

Snow Routine

The snow routine is based on a very simple degree-day approach. When the mean temperature, T, is below the freezing point, precipitation is assumed to fall as snow. It is accumulated in the snow storage until melting conditions occur. When T is above the freezing point the snow remaining in storage is assumed to release an amount of melting water Ps

$$P_S = C_{SMELT} * T \qquad (2.1)$$

proportional to the temperature (T) in degrees Celsius per day. C_{SMELT} is the "degree-day factor" indicating the amount of water melting each day for each degree Celcius above zero.

Surface Storage

In short, the function of this storage is to receive rain and melted snow and to regulate overland flow as well as evaporative losses and interflow.

As long as any water is present in surface storage, the moisture content, U, is continuously reduced by potential evapotranspiration and interflow. The interflow contribution, QIF, is assumed to be proportional to U and to vary linearly with the relative moisture content, L/L_{MAX}, of the lower zone storage.

$$QIF = \begin{cases} CQ_{IF} \dfrac{L/L_{max} - CL_{IF}}{1 - CL_{IF}} U & for \ \dfrac{L}{L_{max}} > CL_{IF} \\ 0 & for \ \dfrac{L}{L_{max}} \le CL_{IF} \end{cases} \qquad (2.2)$$

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L denotes the moisture content of the lower zone storage while the parameters, CQ_{IF} and CL_{IF}, are both positive constants less than unity. CQ_{IF} has the dimension time^{-1} while CL_{IF} is without dimension.

When the surface storage spills, i.e. when $U \geq U_{MAX}$, the excess water, P_N, gives rise to overland flow as well as to infiltration. QOF denotes the part of P_N which contributes to overland flow. It is presumed to be proportional to P_N and to vary linearly with the relative soil moisture content, L/L_{MAX}, of the lower zone storage.

$$QOF = \begin{cases} CQ_{OF} \dfrac{L/L_{max} - CL_{OF}}{1 - CL_{OF}} P_N & for \ \dfrac{L}{L_{max}} > CL_{OF} \\ 0 & for \ \dfrac{L}{L_{max}} \leq CL_{OF} \end{cases} \qquad (2.3)$$

The parameters CQ_{OF} and CL_{OF} are both positive and constants less than unity and without dimension. The dimension of CQ_{OF} is not the same as the dimension of CQ_{IF}, as the dimension of U_{MAX} is different from the dimension of P_N.

Lower Zone Storage

The proportion of net rainfall excess, P_N, that does not run off as overland flow infiltrates into the lower zone storage representing the root zone. A portion, DL, of the amount of infiltration, $(P_N - Q_{OF})$, is assumed to increase the moisture content, L, in the lower zone storage. The remaining amount of infiltrating moisture, G, is assumed to percolate deeper and recharge the groundwater storages. G and DL are calculated from

$$G = \begin{cases} (P_N - CQ_{OF}) \dfrac{L/L_{max} - CL_G}{1 - CL_G} & for \ \dfrac{L}{L_{max}} > CL_G \\ 0 & for \ \dfrac{L}{L_{max}} \leq CL_G \end{cases} \qquad (2.4)$$

$$DL = (P_N - QOF) - G \qquad (2.5)$$

The parameter CL_G, is a positive constant less than unity and without dimension.

As previously mentioned, moisture in the lower zone storage is subject to a consumptive transpiration loss. Evapotranspiration demands are at first attempted to be met at the potential rate from the surface storage. If the moisture content, U, in the surface storage is less than these requirements, the remaining fraction is assumed to be withdrawn by root activity from the lower zone storage at an actual rate. The actual evapotranspiration, E_A, is equal to the potential evapotranspiration, E_P, multiplied by the relative water content, L/L_{MAX}, in the lower zone storage.

$$E_a = E_p * L/L_{max} \tag{2.6}$$

Groundwater storages

The groundwater recharge determined by equation (2.4) is divided into an upper and a lower groundwater storage. CBF_L * G goes into the lower, and $(1-CBF_L)$ * G goes into the upper storage. The parameter, CBFL, is a constant less than unity and without dimension.

The two storages act as linear reservoirs having the time constants, CK_{BFU} and CK_{BFL}. (These linear reservoirs are not to be mixed up with the linear reservoir used for routing the output of the entire NAM model, see figure 2.1.)

The division into two groundwater storages has been made in order to simulate the behaviour of a groundwater reservoir not acting as a single linear reservoir. Note that if CBF_L - 0, only the upper groundwater reservoir is active.

Routing

As indicated in figure 2.1, the interflow and overland flow contributions, QIF and QOF, are routed through two linear reservoirs with time constants CK_1 and CK_2 respectively. The base flow contributions from the upper and lower groundwater storages are routed through the second linear reservoir only.

A linear reservoir is characterized by the outflow being proportional to the water content in the storage. It is in fact assumed that the outflow follows an exponential recession curve. Hence, the outflow at the end of a time step can be calculated by the following expression:

$$Q_{out} = Q_{out,0} * e^{-t/CK} + Q_{in}(1 - e^{-t/CK}) \tag{2.7}$$

where $Q_{OUT,0}$ is the outflow at the end of the previous time step, Q_{IN} is the inflow at the present time step, t is the length of the time step and CK is the time constant of the reservoir.

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Model Parameters

In this section a short description of the model parameters, their physical interpretation and importance is presented along with hints for parameter adjustments in the calibration phase.

Storage capacities: U_{MAX} and L_{MAX} [mm]

These parameters define the upper limit of water content in the upper zone and lower zone storages respectively.

The value of U_{MAX} should reflect that the upper zone is interpreted as water content in interception storage (on vegetation), in surface depression storages and in the uppermost few cm's of the soil.

L_{MAX} can be interpreted as the maximum soil moisture content in the root zone available for the vegetation transpiration. Ideally, L_{MAX} can then be estimated by multiplying the difference between field capacity and wilting point of the actual soil with the effective root depth. However, L_{MAX} represents the average value for an entire catchment; averages for the various soil types and root depth of the individual vegetation types. Therefor, L_{MAX} cannot, in practice, be estimated from field data, but an expected interval within which L_{MAX} is situated may be defined.

As the actual evapotranspiration is highly dependent on the water content of these two storages, U_{MAX} and L_{MAX} are the parameters to be changed in order to adjust the water balance in the simulations.

As a rule, $U_{MAX} = 0.1*L_{MAX}$ can be used unless special catchment characteristics or hydrograph behaviour indicate otherwise.

One important characteristic of the model is that the surface storage must be at a certain threshold level, i.e. $U \geq U_{MAX}$ before any excess water, P_N, occurs. In dry periods, the amount of net rainfall that must fall before any overland flow occurs can be used to estimate U_{MAX}.

Snow Melt Coefficient: C_{SMELT} [mm/°C/day]

This is the degree day coefficient in the routine. When the snow option is not selected, this parameter has no importance and any 'dummy' value can be given.

Overland/Interflow Coefficients: CQ_{OF} [-] and CQ_{IF} [hour^{-1}]

CQ_{OF} is the overland flow runoff coefficient. It is a very important parameter determining the infiltrating quantity and the extent to which excess rainfall runs off as overland flow.

CQ_{OF} is without dimension and has a value between 0 and 1. Physically, in a lumped way it reflects the infiltration and also to some extent the recharge conditions. Small values of CQ_{OF} values are expected for a flat catchment having coarse, sandy soils and a large unsaturated zone; while large CQ_{OF} values are expected for catchments having low, permeable soils such as clay or bare rocks. CQ_{OF} values in the range of 0.01-0.90 have been experienced.

CQ_{IF} is the interflow drainage coefficient. CQ_{IF} determines together with U_{MAX} the amounts of interflow. CQ_{IF} is the quantity of U drained to interflow every hour; therefore, CQ_{IF} is in fact a reciprocal time constant. It is the dominant routing parameter of the interflow because $CQ_{IF} \gg CK_1$, CK_2.

Physical interpretation of the interflow is difficult and will vary somewhat from one catchment to another. As interflow is seldom the dominant stream flow component, CQ_{IF} is usually not a very important parameter. Normally, CQ_{IF} values are in the range of 0.001-0.002 hour^{-1}.

Base flow: CBF_L

CBF_L is responsible for dividing the recharge into two groundwater storages, the upper and the lower one. The only difference between the function of the two reservoirs is the time constants used in routing the recharge to base flow. In cases where base flow is of minor importance or where the base flow recession is well described by an exponential decay, only one of the two reservoirs should be used. This is done by setting CBF_L - 0 implicating that all the recharge goes into the upper groundwater storage.

Threshold Values: CL_{IF}, CL_{OF}, CL_G

these are all positive coefficients less than unity and without dimension. They relate to the relative soil moisture content, L/L_{MAX}, in the interflow, overland flow and recharge equations (2.2), (2.3) and (2.4) respectively. They work as threshold values so that no interflow, overland flow, or recharge is generated if L/L_{MAX} is less than CL_{IF}, CL_{OF}, or CL_G respectively. The function of the threshold value is illustrated by the overland flow equation (2.3) in figure 2.2.

For catchments with alternating dry and wet periods, the threshold values determine the start time of the flow components in the periods were the root zone is being filled up. This can be used in the parameter estimation. For instance, CL_{OF} can be estimated on the basis of such situations where even very heavy rainfall does not give rise to the quick response of the overland flow component.

It should be noticed that the threshold values have no importance in wet periods when $L-L_{MAX}$. The importance of the threshold value varies from catchment to catchment and is usually larger in semi-arid regions.

The parameters are relatively easy to estimate through calibration.

Time Constants for Routing: CK_1, CK_2, $CKBF_U$, $CKBF_L$ [hours]

These four parameters are time constants of respective linear reservoirs, as described above. The time constants are important parameters which can be estimated from hydrograph recession studies. The time constants usually require a short calibration period for estimation (2-3 years) unless the

Figure 2.2 The function of the threshold value in the overland flow equation.

groundwater reservoirs have a very slow response. The length of the calibration period should at least exceed the largest time constant by a factor 2.

2.2 The BAME river network simulation model

The river network simulation model, BAME, is a simplified flow simulation (flood & reservoir routing) model based on linear reservoir routing. This model is suitable specially in the preliminary planning stages to screen development options for further scrutiny of a river network system.

Inflow into the BAME model

Input into the BAME model may be defined in two ways:

1.   By connecting a BAME node with a NAM subcatchment outlet.

2.   By defining the inflow time series at a BAME node.

Model Structure

A river network is represented by *nodes* and *arcs*. Figure 2.3 shows an example of a river network. The nodes are of two types:

1.   *Entering Nodes;* These are the nodes which represent the starting-points of a stream network.

2.   *Internal Nodes;* The other nodes, where routed flow from upstream nodes is entering.

Nodes where observed inflow time series is available for calibration purposes are *control nodes*.

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The nodes are numbered upstream to downstream to account for the principle of water flowing from lower numbered to higher numbered nodes. The entering nodes should be numbered before the internal nodes. The present version of WATSYS is not capable of simulating flow diversion.

A reservoir should best be represented by two nodes in order to save both the inflow and the outflow hydrograph. However, the flow is not to be routed between these nodes by the stream flow routing.
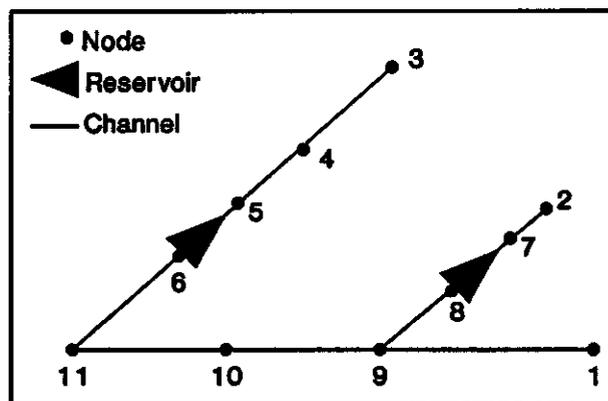
Figure 2.3 Example of a river network represented by nodes and arcs.

Arcs serve as connecting channels between nodes to convey the water between the nodes. In Figure 2.3 the arcs are marked by arrows indicating the flow directions. The routing of the water in the channel is achieved in two ways (see figure 2.4):

1. Shifting of the hydrograph (by a certain time-lag)

2. Attenuation of the hydrograph

For river routing, these two routing instruments will usually be combined, due to the physical distance between the nodes in the river network.

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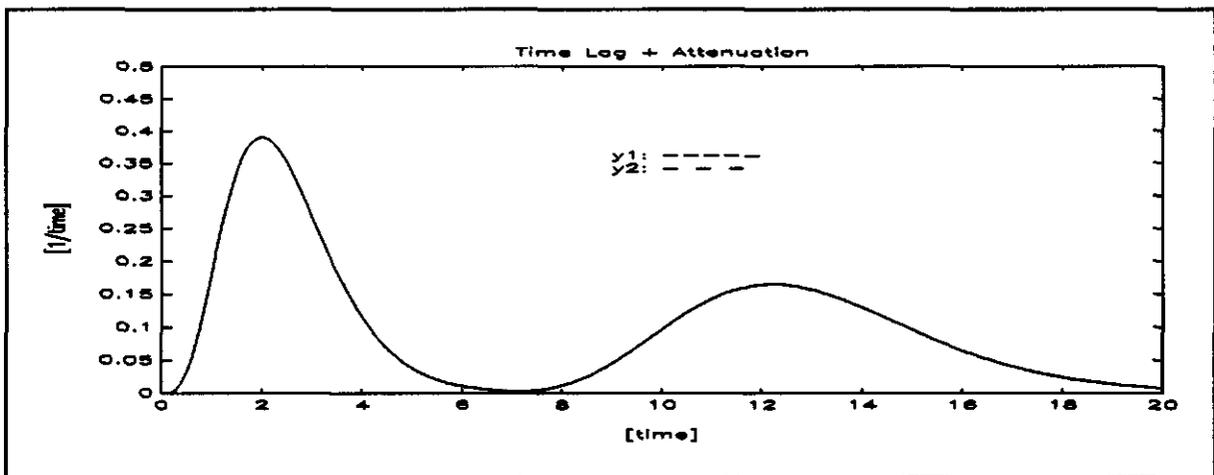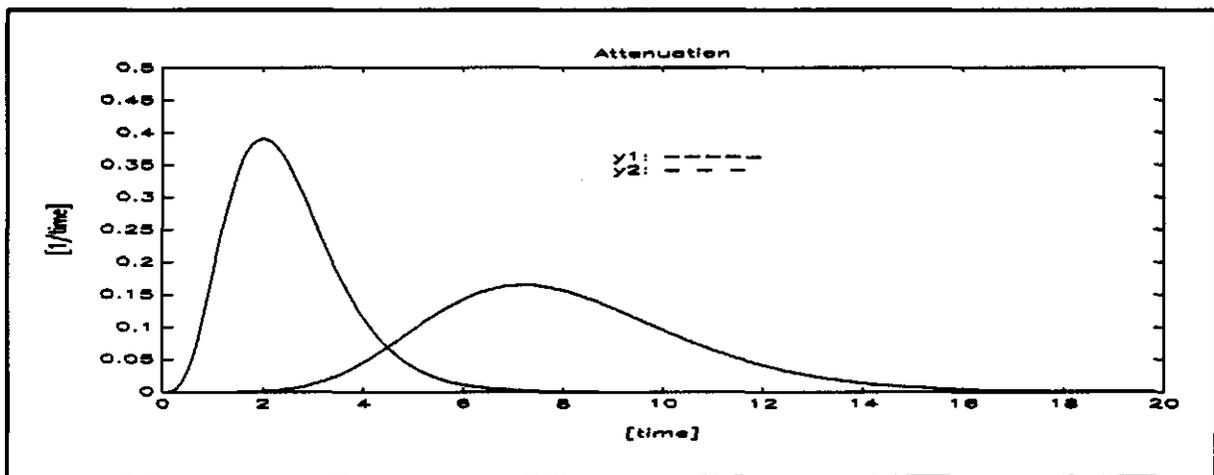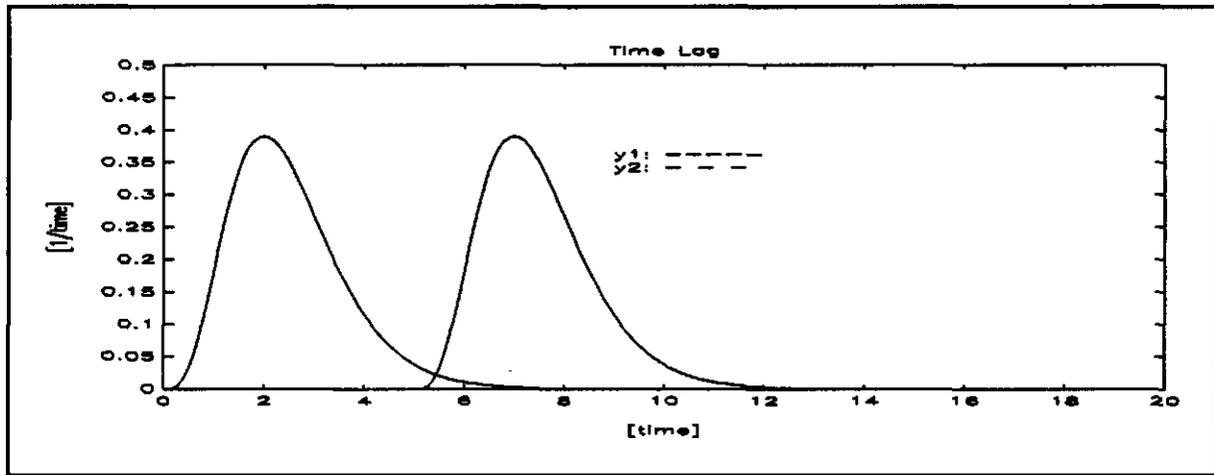
Figure 2.4 River routing by, a) shifting of the hydrograph, b) attenuation of the hydrograph and c) combination of shifting and attenuation of the hydrographs.

In WATSYS two types of *reservoir operation rules* are considered: Flood control reservoirs (two types of release strategies) and conservation reservoirs.

Routing by Linear Reservoirs

The concept of a linear reservoir was implied in an analysis of rainfall and runoff relationship by Zoch (published 1934-1937). He introduced equation (2.8), indicating that in a linear reservoir, the outflow rate is proportional to storage:

$$S = k * Q \tag{2.8}$$

where storage S in $[m^3]$, constant k in $[s]$ and the outflow rate Q in $[m^3/s]$.

Flow may be routed by using a linear reservoir, for instance a unit input:

$$u(0,t) = \frac{1}{k} * e^{-\frac{t}{k}} \tag{2.9}$$

u(0,t) is the unit output at time t for an instantaneous input (duration 0).

In 1957, Nash proposed a conceptual model by considering a drainage basin as n identical linear reservoirs in series (see figure 2.5). By routing an instantaneous input of a unit volume through these reservoirs, a mathematical equation for the IUH (instantaneous unit hydrograph) can be derived:

$$u(0,t) = \frac{1}{k * \Gamma(n)} * (\frac{t}{k})^{n-1} * e^{-\frac{t}{k}} \tag{2.10}$$

where k ($[s]$) is equivalent with the storage coefficient of the reservoirs, n ($[-]$) equals the number of reservoirs in the cascade and $\Gamma(n)$ is the gamma function. For integer values $\Gamma(n) = (n-1)!$. Note that if n equals 1 the cascade would be equivalent with a single linear reservoir (equation 2.9). The present version of WATSYS is restricted to the use of integer values only.
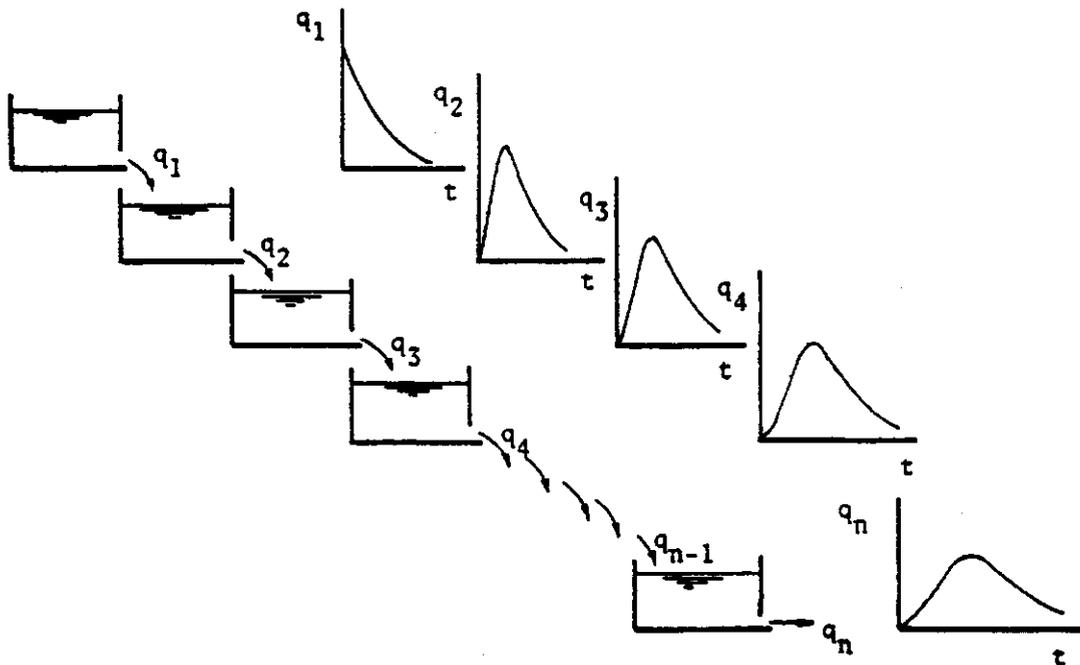
Figure 2.5 Routing of instantaneous inflow through a series of linear storage reservoirs (Nash's model).

These two linear reservoir models (equation 2.9 and 2.10) may be used for routing the streamflow in the BAME model.

A single instantaneous inflow is routed by applying equation (2.11) (the system function):

$$Q_{out}(t) = Q_{in} * u(0, t) \tag{2.11}$$

where Q_{in} ($[m^3]$) is the instantaneous inflow at the upper end of the reach and Q_{out} ($[m^3/s]$) the outflow at the lower end of the reach.

For the convolution of c streams with an instantaneous inflow $Q_{in,i}$ ($[m^3]$) into one main stream (Q_{out}, $[m^3/s]$), equation (2.11) is appropriate:

$$Q_{out}(t) = \sum_{i=1}^{c} [Q_{in,i} * u(0,t)_i]$$ (2.12)

By making the inflow $Q_{in,i}$ time step dependant and change its dimension from [m3] into [m3/s] equation (2.11) may be written as:

$$Q_{out}(t) = \sum_{i=1}^{c} [Q_{in,i}(t) * u(0,t)_i * \Delta t]$$ (2.13)

This equation can now be used to simulate the stream flow at each node in the model.

Reservoir Operation

As mentioned before, two types of reservoir operations are implemented in WATSYS: Flood control and conservation reservoir operation strategies.

<u>Flood Control Reservoirs</u>

Two different flood control release rules are considered:

1.   *Predetermined constant target release*; This is the most common operation strategy for a regulable flood control reservoir. It is to keep the outflow on a constant level. Generally, this so-called target release is equal to the downstream conveyance capacity.
It is a quite reasonable technique, but it can not prevent accidental extreme flooding. More improved strategies are needed to avoid the occurrence of such "major failures".

2.   *Optimal single-reservoir release*; This strategy presumes that the flood inflow time series are known in advance. It then is possible to derive a constant release strategy which ensures:

- The complete utilization of the available storage capacity;

- The selection of a constant release such that $S_{max} = R_{cap}$, where S_{max} is the maximum reservoir filling during the flood and R_{cap} is the reservoir capacity. The constant release Q_r is derived by iterations to ensure the fulfilment of $S_{max} = R_{cap}$. The release Q_r is obtained in order to maximize peak reduction of the outflow hydrograph.

Conservation Reservoir

A conservation reservoir is generally divided into *flood control storage* and *conservation storage*, as shown in Figure 2.6.

The function of flood control in case of a conservation reservoir is similar to that of a flood control reservoir.

The water demand may e.g. consist of drinking water supply demand, irrigation demand, and hydropower demand.

Conservation reservoirs are operated according to the reservoir operation rule curve. The release depends on the time of the year, and the storage level of the reservoir. The operation rule exists of three separate curves, each indicating a different water level in the reservoir (see Figure 2.7):

Figure 2.6 Reservoir storage levels.

1.   Upper limit curve (UL)
2.   Lower limit curve (LL)
3.   Emergency lower limit curve (ELL)
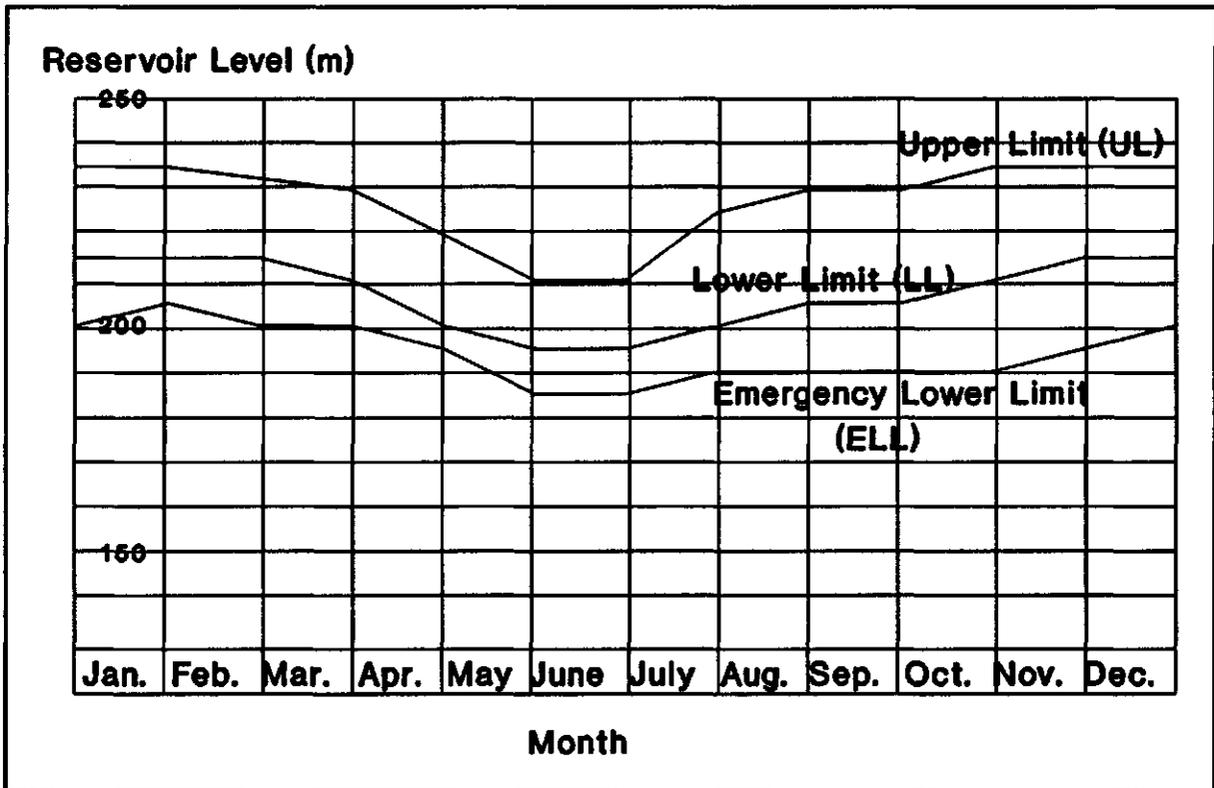
Figure 2.7 Example of a scheme for the reservoir operation rule of a conservation reservoir.

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This scheme is to be interpreted as follows:

- When the water level of a reservoir is between the top of the flood control storage and the top of the conservation storage (UL), releases are made to *draw the reservoir level down to the top of the conservation level.*

- Releases are made equal to the *desired demand* (DD) when the reservoir storage is in between the top of the conservation storage (UL) and the top of the first buffer (LL).

- Releases are made equal to the *required demand* (RD) when the reservoir storage is in between the top of the first (LL) and the top of the second buffer (ELL).

- Releases are made equal to the *discounted required release* (RR * RK) when the storage is between the top of the second buffer (ELL) and the top of the inactive level (RIL).

- *No water is released* when the water level is beneath the top of the inactive level (RIL).

Note: The conservation reservoir operation rule assumes time steps to be 24 hours!

3.   THE PROGRAM WATSYS

3.1   The menu structure in WATSYS

During the loading of the program WATSYS into the memory of the computer
and the initial setting of the model variables, the *title page* is
displayed:

Wageningen Agricultural University Department of Hydrology, Soil Physics & Hydraulics, 1991
WATSYS 2.0 Surface Water Systems Management (Training Model)
by J.J. Bogardi, B.A.H.V. Brorens, S.A. Nielsen, B.P. Shrestha, J.Ch. Wang.

After this, automatically, the *main menu* is presented:

WATSYS Main Menu
1.   Data & File Manipulation
2.   Calculation
3.   Hydrographs
4.   Exit WATSYS
F1—Help   F9—Temp. Exit to DOS   Esc—Exit

A normal use of WATSYS will always lead you from option 1. via 2. and 3. to
4. Only option 1. leads you into an extensive sub menu. As is indicated at
the bottom line of the menu page, help is available by pressing F1, as in
any other decent program. F9 takes you temporarily out of the program into
your MS-DOS operating system. WATSYS is not removed from the memory, so you
will not loose your data. Use the MS-DOS 'EXIT' command to return to the
program.

The 'Esc' key always ends the present displayed 'page' and if mentioned, carries out any related actions. The F1 key and the 'Esc' key are supported by almost each page of the program. The function of the F9 key is different for 'edit-pages'.

Data & File Manipulation

The first option leads you into the 'Data & File Menu':

```
┌─────────────────────────────────────────────────────┐
│                                                       │
│              WATSYS Data & File Menu                  │
│                                                       │
├─────────────────────────────────────────────────────┤
│                                                       │
│              1. Load Data from Files                  │
│                                                       │
│              2. Edit Data                             │
│                                                       │
│              3. Save Data in Files                    │
│                                                       │
│              4. Clear All Data                        │
│                                                       │
├─────────────────────────────────────────────────────┤
│                                                       │
│  F1-Help        F9-Temp. Exit to DOS        Esc-Exit │
└─────────────────────────────────────────────────────┘
```

For the input of data, WATSYS uses eight input files, which you can load using option 1. 'Load Data from Files'. You may edit this data, or any new data by choosing option 2. 'Edit Data'. Option 3. 'Save Data in Files' saves data in files. If you do not save data in files, it will be lost once you exit WATSYS. Advice: Use this option every now and then when during the editing of data and before you start the computation with the model. If you decide to run WATSYS with a completely different data set, choose option 4. 'Clear All Data' to reset all the model variables. It gives you the guarantee that no values from the old data set remain unchanged. Read more about these options in Section 3.2.

Calculation

If you choose the second main menu option, you enter the calculation part of the model:

```
┌─────────────────────────────────────────────────────┐
│                                                     │
│                WATSYS Calculation                   │
│                                                     │
├─────────────────────────────────────────────────────┤
│                                                     │
│      Start the Calculation of the NAM               │
│                                                     │
│            and the BAME model                       │
│                                                     │
│                  (Y/N)                              │
│                                                     │
├─────────────────────────────────────────────────────┤
│                                                     │
│                                                     │
│   F1-Help        F9-Temp. Exit to DOS      Esc-Exit │
└─────────────────────────────────────────────────────┘
```

Start the calculation by pressing either 'y' or 'Y', else 'n' or 'N' or the 'Esc' key. Before starting the calculation, please save your data ! If you did not assign a value to some of the essential model parameters, the model may crash and all your unsaved data will be lost.

Depending on the amount of input data and the computer you are using, the calculation will take a few seconds up to a few minutes.

Calculating only NAM or BAME

If, for some reason, you want to have only one of the models calculated, you have to assign a value of zero to a particular variable in the other model. If you do not want to use the NAM model, you give the variable 'Area of the Subcatchment' of the first subcatchment the value zero. You find this variable under option 2. 'Parameters' of the edit menu. The variable 'Time Constant for Simulation Model', which you find under option 6. of the edit menu, is to be zero if you do not want to calculate the BAME model.

If you skip the NAM or the BAME model, a warning will be displayed saying not all the variables are assigned a value. The program will continue without calculating the concerning model.

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After the calculation, you will be asked to enter a name for the output file containing the results and some important data, or to use the default name 'WATSYS.OUT':

```
┌─────────────── WATSYS Output File ═══════════════┐
│                                                  │
│                                                  │
│        Enter the Name and Extension for the      │
│                                                  │
│        Output File or use this Default:          │
│                                                  │
│                WATSYS.OUT                         │
│                                                  │
├──────────────────────────────────────────────────┤
│                              Esc=Exit & Continue │
└──────────────────────────────────────────────────┘
```

If you press the 'Esc' key, the output is written to the specified file and you get back into the main menu. You may use the 'Temporary exit to DOS' option to examine this file with help of an editor or to print the file.

Hydrographs

WATSYS provides the option of creating hydrographs of the BAME's calculated and observed stream flow. Note: First use the main menu's option 2. 'Calculation' and then this option.

```
┌──────────────────────────────────────────────────┐
│                                                  │
│                WATSYS Hydrographs                │
│                                                  │
├──────────────────────────────────────────────────┤
│                                                  │
│                                                  │
│       1.  Computed Hydrographs                   │
│                                                  │
│       2.  Computed and Observed Hydrograph       │
│                                                  │
│                                                  │
├──────────────────────────────────────────────────┤
│                                                  │
│   F1=Help        F9=Temp. Exit to DOS    Esc=Exit│
└──────────────────────────────────────────────────┘
```

If you want to view only computed hydrographs, with a maximum of two at a time, choose option one and the following screen will appear:

```
┌─────────────── WATSYS Hydrographs ═══════════════┐
║                                                  ║
║                                                  ║
║   Display Hydrograph for Node(s):                ║
║                                                  ║
║   First              5                           ║
║                                                  ║
║   Second             6                           ║
║                                                  ║
║   (For a Hard Copy: Press the "Print Screen"     ║
║                                                  ║
║   Key when the Graph is Displayed)               ║
║                                                  ║
├──────────────────────────────────────────────────┤
║                               Esc=Exit & Display ║
└──────────────────────────────────────────────────┘
```

In this example, the hydrographs for node 5 and 6 will be displayed. For making a hard copy of these hydrographs, press the "print Screen" key when the hydrograph is displayed.

If you want to view an observed hydrograph together with a calculated hydrograph, choose the second option of the hydrographs menu:

```
┌─────────────── WATSYS Hydrographs ═══════════════┐
║         Display Computed and Observed            ║
║                                                  ║
║            Hydrograph for Node:                  ║
║                                                  ║
║                    11                            ║
║                                                  ║
║   (For a Hard Copy: Press the "Print Screen"     ║
║                                                  ║
║   Key when the Graph is Displayed)               ║
├──────────────────────────────────────────────────┤
║                               Esc=Exit & Display ║
└──────────────────────────────────────────────────┘
```

In this example, the observed and the computed hydrograph of node 11 will be displayed.

For examples of hydrographs, see Appendix III.

For producing print outs of hydrographs, you may also use the calculation output file in combination with a program that can produce graphs, like the spreadsheet 'Lotus'.

Exit WATSYS

To exit WATSYS, you either choose option 4. 'Exit WATSYS' or press the 'Esc' key when you are in the main menu. You will see:

```
┌─────────────────────────────────────────┐
│                                         │
│         Are You Sure You Want To         │
│            Exit WATSYS (Y/N)             │
│                                         │
│                                         │
└─────────────────────────────────────────┘
```

You exit WATSYS by pressing 'y' or 'Y'. The 'Esc' key or 'n' or 'N' will take you back to the main menu. Please, do not forget to save your data before you exit the program !

3.2 Loading, Saving and Editing

Loading and saving

The data of the WATSYS model is stored in eight different files with a different extension. Five files for the NAM model data and tree files for the BAME model data (For an example of these files, see the test set on your WATSYS diskette.)

Table 3.1   WATSYS input files and their contents.

Content description:	Extension:
NAM	
Boundary conditions and parameters	.NPF
Initial conditions	.NIF
Hydro-meteorological data: Rainfall	.NRF
Hydro-meteorological data: Evapotranspiration	.NEF
Hydro-meteorological data: Temperature	.NTF
BAME	
Model data	.BDF
Inflow time series	.BQF
Observed stream flow series at control nodes.	.BOF

To load these files, choose option 1. 'Load Data from Files' of the Data & File Menu. You will then get the load screen as shown in appendix I. It is almost similar to the save screen, also shown in this appendix.

Once in the load or the save screen, you may use the following keys:

Table 3.2   Keys for the loading and saving of files.

For entering filenames:

All the keys that represent characters allowed in filenames (a-z, A-Z, 0-9, ., ~, !, @, #, $, %, ^, &, (,), _, {, and }) and the delete and backspace key.

For moving the cursor:

Arrow keys:	As displayed on the arrow
Page Up:	Top of the page
Page Down:	End of the page
Control-Home:	Top of the page
Control-End:	End of the page

Other:

F1:	Help
F2:	Quit the loading or saving, no files are being loaded or saved.
Esc:	Exit and start the loading or saving.

If you enter files that could not be found by the program (they have to be in the current directory), or if there was an error detected in a file, you will get a warning or an error message (see Section 3.3). The files that could be found or the correct files will be loaded anyway. This to provide the opportunity of loading as much data as possible, in case of a failure.

<u>Editing</u>

The choice for option 2. 'Edit Data' in the data and file menu will give you the following screen:

```
┌─────────────────────────────────────────────────────────────┐
│                                                             │
│                    WATSYS Edit Menu                         │
│                                                             │
├─────────────────────────────────────────────────────────────┤
│                                                             │
│    NAM Data              ·                                  │
│         1.      Boundary Conditions                         │
│         2.      Parameters                                  │
│         3.      Initial Conditions                          │
│         4.      Hydro-Meteorological Data                   │
│    Connection NAM-BAME                                      │
│         5.      Subcatchments->Nodes                        │
│    BAME Data                                                │
│         6.      Basic Model Data                            │
│         7.      Node Characteristics                        │
│         8.      Interconnections                            │
│         9.      Inflow & Observed Stream flow               │
│         0.      Conservation Reservoirs                     │
│                                                             │
├─────────────────────────────────────────────────────────────┤
│                                                             │
│    F1-Help      F9-Temp. Exit to DOS         Esc-Exit       │
└─────────────────────────────────────────────────────────────┘
```

The first four options provide the possibility of making changes in the *NAM model data*.

1. *Boundary Conditions;* Here you define the rough structure of your model (the starting and the ending dates, the length of the time steps and the number of subcatchments). If you only use the BAME model, you still have to fill in the variables in the upper part of this screen.

2. *Parameters;* These are input variables that do not depend in any way on the 'hydro-meteorological history' of a subcatchment, but on the geological and soil-physical characteristics (e.g. area, threshold values, time constants). Each subcatchment has its own parameters.

3. *Initial conditions;* Variables that describe the initial hydrological situation in a subcatchment are found here (amounts of water in storages and flow values). They are assigned different values for each subcatchment.

4. *Hydro-meteorological data;* Here the precipitation, the evapotranspiration and the temperature for each time step and subcatchment is to be entered. The temperature may be ignored if no snow routine is used.

The fifth option is for *connecting the NAM to the BAME model.*

5.   *Subcatchments -> Nodes;* In a table the outflow from each NAM subcatchment is directed into a BAME node.

The last six options are for editing any *BAME model data.*

6.   *Basic model data;* The number of the river's network nodes and entering nodes as well as some parameters used for the simulation are to be entered.

7.   *Node characteristics;* For each node some important characteristics have to be given (inflow type, control node ?, reservoir ?, type of reservoir).

8.   *Interconnections;* Here is to be indicated from which node to which node the stream flows, if this flow is to be routed (Nash cascade) and what the parameters of this cascade should be. The conveyance capacity of the river between two nodes is to be filled in case the optimal single-reservoir release rule is used for a flood reservoir.

9.   *Inflow & observed stream flow;* Possible inflow of water other than from the NAM model, as well as any observed (measured) stream flow is to be entered for each node. The observed stream flow is used for making hydrographs only.

0.   *Conservation reservoirs;* If you used option 7. to define a reservoir as a conservation reservoir, you have to use this option for defining the precise characteristics.

In the edit screens, you may use the following keys:

Table 3.3   Keys for the loading and saving of files.

For entering data:

The keys 0-9, '.' and the delete and backspace key.

For moving the cursor:

Arrow keys:	As displayed on the arrow
Page Up:	Top of the page
Page Down:	End of the page
Home:	First column
End:	Last column
Control-Home:	Top of the page in the first column
Control-End:	End of the page in the last column
Tab:	The next column
Shift-tab:	The previous column
Return:	From left to right and top to end.

Other:

These keys only function if they are mentioned at the bottom of a page:

F1:	'Help'	Gives a help screen.
F2:	'Undo'	Removes your latest changes, brings back the previous values.
F3:	'Overview'	Shows the BAME node interconnection.
F4:	'Next ..'	Brings you the next node or subcatchment.
F5:	'Prev. ..'	Brings you the previous node or subcatchment.
F9:	'Page Up'	Displays next page.
F10:	'Page Down'	Displays the previous page.
Esc:		Exit.

Note: Until you press any of the keys 'F4', 'F5','F9','F10' or 'Esc', no real changes are made to the data, so it is possible to recover the old values with help of the 'F2' key. (Do not mix up the values stored in your input files with these values ! The program never makes changes to your files unless you overwrite files by saving them with equal names as already existing ones (option 3. in the data and file menu). The values mentioned here are only present in the memory of the computer.)

3.3   Error messages and warnings

In this section the error messages and warnings generated by WATSYS are elucidated.

General error message

```
┌──────────  WATSYS Error  ──────────┐
│                                     │
│  The Display File "            "    │
│                                     │
│  Could not be Found. Copy this      │
│                                     │
│  File from your Original WATSYS     │
│                                     │
│  Disk to the Current Directory.     │
│                                     │
│  Continuing will not crash WATSYS.  │
│                                     │
└─────────────────────────────────────┘
```

WATSYS uses the DOS command 'TYPE' for displaying the contents of the display files (*.DIS). The in the error message mentioned file could not be found. Check if this file is in the current directory or copy the file from your original WATSYS diskette. You may continue the program without this file, but then you will have to work 'in the dark'.

Edit error messages

```
┌──────────  WATSYS Error  ──────────┐
│                                     │
│   You Entered an illegal Value      │
│                                     │
│      Please Try again  !!           │
│                                     │
└─────────────────────────────────────┘
```

The entered value could not be read due to an incorrect format. (for example you entered '2..3' instead of '2.3', or a real value (like '2.3') where only integer values (like '2') may be used. Go back to the concerning page and re-enter the data.

A format is a characterisation of the way a value has to be read or written by the program. If this characterisation is ignored by the user, FORTRAN will produce an error message and the program will be aborted. This FORTRAN error message is therefore replaced by a WATSYS error message.

```
┌──────────── WATSYS Error ════════────┐
│                                       │
│   You Previously Entered a Value      │
│                                       │
│    with an Illegal Format.            │
│                                       │
│  This Value is Replaced by Zeroes.    │
│                                       │
│   Please Re-enter this Value !!       │
│                                       │
└───────────────────────────────────────┘
```

A previously entered value had the wrong format, it was too big. For example, the official format of a value declares that the value should not be bigger than 999.99, but you entered '2300.0'.

```
┌──────────── WATSYS Error ════════────┐
│                                       │
│    You Used an Illegal Date           │
│                                       │
│     for the Begin or End of           │
│                                       │
│       the Experiment !!               │
│                                       │
└───────────────────────────────────────┘
```

An entered date is impossible (like 'january 35, 1990').

```
┌──────────── WATSYS Warning ════════──┐
│                                       │
│  Warning !!  The Number of Time Steps │
│                                       │
│   is more than 100 or limited to 1.   │
│                                       │
│  This  Value is changed to 100 or to 1.│
│                                       │
└───────────────────────────────────────┘
```

The number of time steps is calculated with help of the dates and the length of the time steps, upon leaving the screen of option 1. in the edit menu. The maximum value is 100. If this value is exceeded, it is automatically adjusted to 100. The date of the end of the experiment is then no longer significant.
If the date of the end of the experiment is before the date of the beginning of the experiment, the number of time steps will be limited to 1. In that case the number of time steps is made equal to 1.

```
┌──────────────── WATSYS Error ════════════════┐
│                                              │
│   The Number of Subcatchments                │
│                                              │
│   has to be between 1 and 13 !!              │
│                                              │
└──────────────────────────────────────────────┘
```

The maximum number of subcatchments in the NAM model is 13. If you want to
use more than 13 subcatchments, run the NAM model more than once for
different sets of (13) subcatchments and use the NAM output in the WATSYS
output file(s) as input for the BAME input time series (edit menu option
9.). You may use an editor and/or a spreadsheet program for adjusting the
WATSYS output file(s) to the right WATSYS input file (*.BQF).

Load error messages

```
┌──────────────── WATSYS Error ════════════════┐
│  These Files could not be Found, or You Used │
│                                              │
│  Illegal Names:                              │
│                                              │
│                                              │
│                                              │
│                                              │
│                                              │
│                                              │
│                                              │
│                                              │
│   If You want to use the Data in one of these│
│                                              │
│   Files then Retry the Loading or Saving !   │
└──────────────────────────────────────────────┘
```

The mentioned files could not be found by WATSYS. Check their names, they
have to be present in the current directory. The files that can be found
will be loaded, although in some cases variables from one file are
necessary to read data from other files. In that case an error message will
be displayed saying 'An error occurred reading file(s): ... '. The data in
these files may still be loaded, use the edit option to check this.

```
┌══════════════════ WATSYS Error ══════════════════┐
║                                                   ║
║        An Error Occurred Reading File(s):         ║
║                                                   ║
║                                                   ║
║                                                   ║
║                                                   ║
║                                                   ║
║                                                   ║
║                                                   ║
║        Probably (Part) of the Data was not Loaded.║
║        A Read Error may be caused by a Signalised ║
║           Read Error in a Preceding File.         ║
║                                                   ║
└═══════════════════════════════════════════════════┘
```

An error was detected when reading the mentioned file. The error may caused
by an incorrect input file, or by a read error in a previously mentioned
file. You may try to correct the error with help of an editor or a
spreadsheet and for example existing (or for this purpose produced) input
files. Note: It is important that the data is at exact the correct place in
the input file.

Calculation warning messages

```
┌═════════════ WATSYS Warning ═════════════┐
║                                          ║
║     Not all Data is Present for          ║
║                                          ║
║     Running the NAM model !!             ║
║                                          ║
║     WATSYS will proceed with             ║
║                                          ║
║     Running the BAME model.              ║
║                                          ║
└══════════════════════════════════════════┘
```

This message is displayed when the variable 'Area of the subcatchment' of
subcatchment 1 in option 2. of the edit menu has the value zero. To prevent
the program from crashing when not all the data is present, this message is
displayed and the NAM model is skipped. If you only want to calculate the
BAME model, assign the mentioned variable the value zero.

```
┌═════════════ WATSYS Warning ═════════════┐
║                                          ║
║     Not all Data is Present for          ║
║                                          ║
║     Running the BAME model !!            ║
║                                          ║
└══════════════════════════════════════════┘
```

This message is displayed when the variable 'Time constant for simulation model' in option 6. of the edit menu has the value zero. To prevent the program from crashing when not all the data is present, this message is displayed and the BAME model is skipped. If you only want to calculate the NAM model, assign the mentioned variable the value zero.

Hydrograph error message

```
┌──────────── WATSYS Error ════════════┐
│                                       │
│   You Entered an illegal Filename     │
│                                       │
│        Please Try again  ! !          │
│                                       │
└───────────────────────────────────────┘
```

The entered filename was not a valid MS-DOS filename.

Other error messages and never ending loops

Any other error messages than these mentioned above are not given by WATSYS but by FORTRAN. For example:

run-time error M6101: MATH
- floating-point error: invalid

The program is aborted and all your unsaved data is lost.

Errors like this can occur when the NAM or the BAME model is calculated with insufficient data. The program encounters for example a division by zero and crashes. In other cases, the program might get stuck in a never ending loop. Although a lot effort was put in preventing this type of errors, one can never be sure. Please always save your data before you start the calculation of the model.

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APPENDIX I   WATSYS Menu and corresponding help screens

> Main Menu:

```
┌─────────────────────────────────────────────────────────┐
│                                                         │
│         WATSYS Main Menu                                │
│                                                         │
├─────────────────────────────────────────────────────────┤
│                                                         │
│    1.   Data & File Manipulation                        │
│                                                         │
│    2.   Calculation                                     │
│                                                         │
│    3.   Hydrographs                                     │
│                                                         │
│    4.   Exit WATSYS                                     │
│                                                         │
├─────────────────────────────────────────────────────────┤
│                                                         │
│   F1=Help      F9=Temp. Exit to DOS      Esc=Exit       │
│                                                         │
└─────────────────────────────────────────────────────────┘
```

35

WATSYS Main Menu:

1. Data & File Manipulation: Choose this option for loading data from files, edit data, save data in files and clear data.

2. Calculation: The calculation of WATSYS (NAM and BAME).

3. Hydrographs: View hydrographs of the output of WATSYS.

4. Exit WATSYS: Exit the program. Please, remember to save your data !

F1: This page. Throughout the program F1 provides topical information.

F9: Temporary exit to DOS. WATSYS remains in the memory of the computer, but you may use any MS-DOS command or other program, as long as it fits in the memory. You return to WATSYS by entering the DOS command 'EXIT'.

Esc: The 'Esc' key on your computer. Use this key throughout WATSYS for ending certain operations. In this case to exit the program. You may also choose option 4.

Note: A normal use of WATSYS leads you from option 1. via 2. and 3. to 4.

> Main Menu Option 1:

```
┌─────────────────────────────────────────────────────────┐
│                                                         │
│  WATSYS Data & File Menu                                │
│                                                         │
├─────────────────────────────────────────────────────────┤
│                                                         │
│       1. Load Data from Files                           │
│                                                         │
│       2. Edit Data                                      │
│                                                         │
│       3. Save Data in Files                             │
│                                                         │
│       4. Clear All Data                                 │
│                                                         │
├─────────────────────────────────────────────────────────┤
│                                                         │
│  F1=Help     F9=Temp. Exit to DOS        Esc=Exit       │
│                                                         │
└─────────────────────────────────────────────────────────┘
```

WATSYS Data & File Menu:

1. Load Data from Files: Choose this option for loading data from the WATSYS input files.

2. Edit Data: Enter the WATSYS editing menu. Change loaded data or enter new data.

3. Save Data in Files: Save the data present in the memory of the computer in files. Hint: You can never save your data too often, as computers (or programs) will crash every now and then. Use this option preferably before you start the calculation, as mathematical errors due to a lack of data may cause WATSYS to crash.

4. Clear All Data: This option initialises all the program variables. This is done automatically when you start up WATSYS. Use this option when you want to use a different data set, to make sure no old data remains in the memory of your computer. Note: Save any changed old data first, as it will be lost.

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```
                        WATSYS File Loading
  ┌─────────────────────────────────────────────────────────────────┐
  ║                                                                   ║
  │  NAM model input files:                                           │
  │                                                                   │
  │    Boundary Conditions and Parameters           sulm      .NPF    │
  │    Initial Conditions                           sulm      .NIF    │
  │    Hydro-Meteorological Data: Rainfall          sulm      .NRF    │
  │    Hydro-Meteorological Data: Evapotranspiration sulm     .NEF    │
  │    Hydro-Meteorological Data: Temperature       sulm      .NTF    │
  │                                                                   │
  ├───────────────────────────────────────────────────────────────── │
  │                                                                   │
  │  BAME model input files:                                          │
  │                                                                   │
  │    Model Data                                   sulm      .BDF    │
  │    Inflow Time Series                           sulm      .BQF    │
  │    Observed Stream Flow Series at Control Nodes sulm      .BOF    │
  │                                                                   │
  ╚═══════════════════════════════════════════════════════════════════╝
```

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Boundary conditions and parameters: Contains data of first two options in the edit menu.

Initial conditions: Contains data of third option in edit menu.

Hydro-meteorological data, rainfall: Contains rainfall data of fourth option in edit menu.

Hydro-meteorological data,evapotranspiration: Contains evapotranspiration data of fourth option in edit menu.

Hydro-meteorological data, temperature: Contains temperature data of fourth option in edit menu.

Model data: Contains all data of option 5. to 8. and 0. in the edit menu.

Inflow time series: Contains inflow data of option 9. in the edit menu.

Observed stream flow series ...: Contains the observed stream flow data of option 9. in the edit menu.

Each file can have a different name. The extensions listed on the right are used. If a file can not be found, or if a file is corrupt, you will get an error message. WATSYS will try to read the other files, but you may get more warnings or error messages. Use the edit menu to check what data has been loaded.

F1: this page; F2: Quit and do not load or save;
Esc: Exit and start to load or save files.

\> **Data & File Menu Option 2:**

```
                        WATSYS Edit Menu

NAM Database
    1.    Boundary Conditions
    2.    Parameters
    3.    Initial Conditions
    4.    Hydro-Meteorological Data
Connection NAM-BAME
    5.    Subcatchments->Nodes
BAME Database
    6.    Basic Model Data
    7.    Node Characteristics
    8.    Interconnections
    9.    Inflow & Observed Stream flow
    0.    Conservation Reservoirs


F1=Help       F9=Temp. Exit to DOS        Esc=Exit
```

General help on editor keys:

> For entering data:
The keys 0-9, '.', and the delete and backspace key.

> For Moving the cursor:
Arrow keys   As displayed on the arrow.
Return   From left to right and top to end.
Page Up/Page Down   Top/End of the page.
Home/End   First/Last column.
Control-Home/End   Top/End of page in First/Last column
Tab/Shift-Tab   Next/Previous column.

> These keys only function if they are mentioned at the bottom of a page:
F1 Help   Gives a help screen.
F2 Undo   Removes your latest changes, brings back the old values.
F3 Overview   Shows the BAME node interconnection.
F4 Prev ...   Brings you the next node or subcatchment.
F5 Next ...   Brings you the previous node or subcatchment.
F9 Page Up   Brings you the next page.
F10 Page Down   Brings you the previous page.
Esc Exit   Exit the present page and return to the edit menu.

>Data & File Menu Option 3:

WATSYS File Saving

NAM model input files:

Boundary Conditions and Parameters   sulm   .NPF
Initial Conditions   sulm   .NIF
Hydro-Meteorological Data: Rainfall   sulm   .NRF
Hydro-Meteorological Data: Evapotranspiration   sulm   .NEF
Hydro-Meteorological Data: Temperature   sulm   .NTF

BAME model input files:

Model Data   sulm   .BDF
Inflow Time Series   sulm   .BQF
Observed Stream Flow Series at Control Nodes   sulm   .BOF

Boundary conditions and parameters: Contains data of first two options in the edit menu.
Initial conditions: Contains data of third option in edit menu.
Hydro-meteorological data, rainfall: Contains rainfall data of fourth option in edit menu.
Hydro-meteorological data,evapotranspiration: Contains evapotranspiration data of fourth option in edit menu.
Hydro-meteorological data, temperature: Contains temperature data of fourth option in edit menu.

Model data: Contains all data of option 5. to 8. and 0. in the edit menu.
Inflow time series: Contains inflow data of option 9. in the edit menu.
Observed stream flow series ...: Contains the observed stream flow data of option 9. in the edit menu.

Each file can have a different name. The extensions listed on the right are used. If a file can not be found, or if a file is corrupt, you will get an error message. WATSYS will try to read the other files, but you may get more warnings or error messages. Use the edit menu to check what data has been loaded.

F1: this page; F2: Quit and do not load or save;
Esc: Exit and start to load or save files.

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> Data & File Menu Option 4:

```
┌─────────────────────────────────────────────┐
│                                             │
│   Are You Sure You Want to Clear All Data ? │
│                                             │
│   All the Unsaved Data Will be Lost !!      │
│                                             │
│              (Y/N)                          │
│                                             │
├─────────────────────────────────────────────┤
│                                             │
│  F1=Help                           Esc=Exit │
└─────────────────────────────────────────────┘
```

WATSYS Clear All Data:

This option initialises all the program variables. This is done automatically when you start up WATSYS. Use this option if you want to use a different data set, to make sure no old data remains in the memory of your computer.

Note: Save any changed old data first, as it will be lost.

```
┌─────────────────────────────────────────────────┐
│                                                 │
│           WATSYS Calculation                    │
│                                                 │
├─────────────────────────────────────────────────┤
│                                                 │
│                                                 │
│        Start the Calculation of the NAM         │
│                                                 │
│             and the BAME model                  │
│                                                 │
│                   (Y/N)                          │
│                                                 │
├─────────────────────────────────────────────────┤
│                                                 │
│  F1=Help    F9=Temp. Exit to DOS     Esc=Exit   │
│                                                 │
└─────────────────────────────────────────────────┘
```

For starting the calculation enter 'Y' or 'y', else 'N', 'n' or 'Esc'.
First the NAM model is calculated, then the BAME model. After the calculation
you are asked to enter a filename for the output file or to use the default
filename 'WATSYS.OUT'.

Calculating the NAM model only: WATSYS will not start the calculation of the
   BAME model if you give the variable 'Time Constant for simulation model'
   in option 6. of the edit menu the value 0. A warning is displayed that
   the BAME model will not be calculated.

Calculating the BAME model only: WATSYS will not start the calculation of the
   NAM model if you give the variable 'Area of the Subcatchment' of the first
   subcatchment in option 2. of the edit menu the value 0. A warning is
   displayed that the NAM model will not be calculated.

Note: If you try to calculate the model with incorrect data, the program might
   crash on a mathematical error (like division by zero), in which case you loose
   all your unsaved data. A lot of effort was spend on trying to prevent these
   errors from happening, but full safety cannot be guaranteed. So:

                PLEASE, SAVE YOUR DATA BEFORE YOU START THE CALCULATION !!

> **Main Menu Option 3:**

WATSYS Hydrographs
1. Computed Hydrographs
2. Computed and Observed Hydrograph
F1=Help   F9=Temp. Exit to DOS   Esc=Exit

1. Computed Hydrographs: Choose this option to view one or two of the calculated hydrographs of the BAME model.

2. Computed and Observed Hydrograph: If you previously entered observed stream flow data for a node (option 9. of the edit menu), you may use this option to view the calculated and the observed hydrograph in one figure.

Hard Copy: If you want to make a hard copy of a graph, press the 'Print Screen' key on your machine when the graph is displayed. If this does not work, give the DOS command 'GRAPHICS' before you start WATSYS.

Problems: For using this hydrograph facility, a CGA, EGA or VGA display, or a display that supports simulating one of these modes (run the simulation program before you start WATSYS) is necessary.

```
┌─────────────────────────────────────────────────┐
║                                                 ║
║           WATSYS Hydrographs                    ║
║                                                 ║
║   Display Hydrograph for Node(s):               ║
║                                                 ║
║   First        ...                              ║
║                                                 ║
║   Second       ...                              ║
║                                                 ║
║   (For a Hard Copy: Press the "Print Screen"    ║
║                                                 ║
║   Key when the Graph is Displayed)              ║
║                                                 ║
║                            Esc—Exit & Display   ║
║                                                 ║
└─────────────────────────────────────────────────┘
```

```
┌─────────────────────────────────────────┐
│  ═══════ WATSYS Hydrographs ═══════      │
│                                          │
│   Display Computed and Observed          │
│                                          │
│      Hydrograph for Node:                │
│                                          │
│                                          │
│            . . .                         │
│                                          │
│   (For a Hard Copy: Press the "Print Screen" │
│                                          │
│   Key when the Graph is Displayed)       │
│                                          │
│                    Esc=Exit & Display    │
└─────────────────────────────────────────┘


> Main Menu Option 4:


┌─────────────────────────────────────────┐
│                                          │
│   Are You Sure You Want To               │
│     Exit WATSYS (Y/N)                    │
│                                          │
└─────────────────────────────────────────┘
```

APPENDIX II   WATSYS Edit and corresponding help screens

> Edit Menu Option 1:

```
┌─────────────────────────────────────────────────────────────────┐
│  WATSYS NAM Experiment Boundary Conditions                      │
│                                                                  │
│  TIME:                                                           │
│                                                                  │
│          Year  Month  Day  Hour                                 │
│                                                                  │
│  Begin   1978    5    11   12                                   │
│                                                                  │
│  End     1978    6    30   12                                   │
│                                                                  │
│  Timestep Duration [hours]:        12                           │
│                                                                  │
│  Total Number of Time steps :     100                           │
│  (Maximum=100)                                                  │
│                                                                  │
├─────────────────────────────────────────────────────────────────┤
│  SUBCATCHMENTS:                                                  │
│                                                                  │
│  Total Number of Subcatchments in the Experiment:     13        │
│  (Maximum=13)                                                   │
│                                                                  │
└─────────────────────────────────────────────────────────────────┘
```

F1Help F2Undo   EscExit

TIME: Enter the date and time of the begin of the experiment and the date and time where it stops.

Timestep duration: Enter the length of the time steps to be used, in hours.

Total number of time steps: This value is calculated by the program upon pressing the 'Esc' key. The maximum value is 100. WATSYS will change this value if it is limited to 1 or larger than 100.

Total number of subcatchments in the experiment: The number of subcatchments you want to use for the NAM model. The maximum value is 13.

Note: If you only use the BAME model, you still have to fill in the variables above the line (date, time, timestep duration).

> **Edit Menu Option 2 (Page 1 of 2):**

WATSYS NAM Model Parameters

Subcatchment 1 of 13 | Page 1 of 2

TOPOGRAPHY
  Area of the Subcatchment   4.   km²
  Ratio of Groundwater Catchment Area to
    Topographical Area (Typically = 1.00)   1.00

STORAGE
  Maximum Water Content in Surface Storage   1.00   mm
  Maximum Water Content in Rootzone Storage   150.00   mm

OVERLAND FLOW
  Overland Flow Runoff Coefficient (0-1)   .20
  Rootzone Threshold Coefficient for Overland Flow (0-1)   .50

INTERFLOW
  Time Constant for Interflow   .0010   1/hr
  Rootzone Threshold Coefficient for Interflow (0-1)   .80

Area of the subcatchment: If you only want to use the BAME model, this value
    of subcatchment 1 has to be zero.
Ratio of groundwater catchment ...: Used for adjusting the size of the
    catchment for routing the baseflow.
Maximum water content in surface storage: The maximum amount of water
    intercepted on vegetation, in surface depression storages and the upper
    few cm's of the ground. (See manual: Umax).
Maximum water content in rootzone storage: Max. soil moisture content in the
    root zone available for the vegetative transpiration. (See manual: Lmax).
Overland flow runoff coefficient: Important parameter determining the extent
    to which excess rainfall runs off as overland flow. (See manual: CQof).
Rootzone threshold .. overl. ..: Overland flow is generated only if this value
    is less than the ratio of the soil moisture content present in the rootzone
    and the maximum water content in the rootzone (Lmax). (See manual: CLof).
Time constant for interflow: The interflow drainage coefficient, it determines
    the quantity of the water in the surface storage drained to interflow every
    hour. (See manual: CQif).
Rootzone threshold .. inter. ..: Interflow is generated only if this value is
    less than the ratio of the soil moisture content present in the rootzone
    and the maximum water content in the rootzone (Lmax). (See manual: CLif).

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WATSYS NAM Model Parameters

Subcatchment 1 of 13   Page 2 of 2

GROUNDWATER FLOW
Time Constant for Upper Groundwater Reservoir
   (Baseflow Recession)   96. hr
Time Constant for Lower Groundwater Reservoir
   (Baseflow Recession)   0. hr
Fraction of Groundwater reaching the Lower
   Groundwater Reservoir (0 = Lower GR inactive)   .00
Rootzone Threshold coeff. for Groundwater Recharge (0-1)   .90

FLOW ROUTING
Time Constants for Routing of Overland and Interflow   3.00 hr
Time Constant for Routing of Total Runoff   .00 hr

SNOW ROUTINE
Snow Routine Included ? (1=Yes; 0=No)   0
Degree-Day Factor in Snow Routine   .00mm/°C/Day

F1Help F2Undo F4Prev SubCatch F5Next SubCatch F9Page Down F10Page Up EscExit

Time const. upper gr. res.: The storage acts as a linear reservoir, this is the corresponding time constant (see manual: CKBFU).

Time const. lower gr. res.: The storage acts as a linear reservoir, this is the corresponding time constant (see manual: CKBFU).

Fraction of groundw. reaching lower groundw. reservoir: Fraction of the total amount of water that is routed to the groundwater reservoirs that enters the lower reservoir. If the value is 0.0, the lower reservoir will be inactive and only one reservoir will be used.

Rootzone threshold coeff. for groundwater flow: Water is routed to the ground water reservoirs only if the relative soil moisture content (the ratio of the amount of water present in the rootzone and the maximum amount of water) is larger than this threshold coefficient.

Time constants for overland flow and interflow: The runoff originating from overland flow and interflow is routed through a linear reservoir, this is the corresponding time constant.

Time constant for total runoff: The total runoff is routed through a linear reservoir, this is the corresponding time constant. Note: The runoff from overland flow and interflow is routed twice !

Remark: This last routing may be replaced by the routing of the BAME model.

Snow routine included: When the mean temperature is below freezing point, the precipitation is assumed to fall as snow. It is accumulated in the snow storage until melting conditions occur. Note: This value is the same for each subcatchment.

Degree-day factor: Amount of water released from the snow storage proportional to the temperature (above zero).

> Edit Menu Option 3:

WATSYS NAM Model Initial Conditions

Subcatchment 1 of 13

WATER CONTENT
  Water Content in Snow Storage   .00 mm
  Water Content in Surface Storage   1.00 mm
  Water Content in Rootzone Storage   100.00 mm
OVERLAND FLOW ROUTING
  Overland Routing with Overland and Interflow Component   .000 mm/hr
  Overland Routing with Total Runoff Component   .000 mm/hr
INTERFLOW ROUTING
  Interflow Routing with Overland and Interflow Component   .000 mm/hr
  Interflow Routing with Total Runoff Component   .000 mm/hr
BASEFLOW
  Baseflow from Upper Groundwater Reservoir Routing
    without total Runoff Component   .000 mm/hr
  Baseflow from Upper Groundwater Reservoir Routing
    with total Runoff Component   .000 mm/hr
  Baseflow from Lower Groundwater Reservoir Routing
    without total Runoff Component   .000 mm/hr
  Baseflow from Lower Groundwater Reservoir Routing
    with total Runoff Component   .000 mm/hr

F1Help F2Undo F4Prev SubCatch F5Next SubCatch F9Page Down F10Page Up EscExit

WATER CONTENT: The amount of water (in [mm]) present in a subcatchment in the specified storage at the beginning of a simulation.

Overland routing with overland and interflow component: The initial amount of overland flow that is routed through the linear reservoir for overland and interflow.

Overland routing with total runoff component: The initial amount of overland that is routed through the linear reservoir for total runoff routing.

Interflow routing with overland and interflow component: The initial amount of interflow that is routed through the linear reservoir for overland and interflow.

Interflow routing with total runoff component: The initial amount of interflow that is routed through the linear reservoir for total runoff routing.

Baseflow Upper G.R. without total runoff component: The initial amount of baseflow routed through the linear reservoir of upper baseflow.

Baseflow Upper G.R. with total runoff component: The initial amount of baseflow originating from the upper G.R. that is routed through the linear reservoir of total runoff.

Baseflow Lower G.R. without total runoff component: The initial amount of baseflow routed through the linear reservoir of lower baseflow.

Baseflow Lower G.R. with total runoff component: The initial amount of baseflow originating from the lower G.R. that is routed through the linear reservoir of total runoff.

WATSYS NAM Hydro-Meteorological Data

| Subcatchment 1 of 13 | | | | 100 Time Steps of 12 hours | |

Step	Date	Hour	Precipitation [mm/hr]	Evapotransp. [mm/hr]	Temperature [°C]
1	11- 5-1978	12	.00	.08	.00
2	11- 5-1978	24	.00	.08	.00
3	12- 5-1978	12	.00	.08	.00
4	12- 5-1978	24	.00	.08	.00
5	13- 5-1978	12	.00	.08	.00
6	13- 5-1978	24	.33	.08	.00
7	14- 5-1978	12	.21	.08	.00
8	14- 5-1978	24	.21	.08	.00
9	15- 5-1978	12	.15	.08	.00
10	15- 5-1978	24	.15	.08	.00
11	16- 5-1978	12	.03	.08	.00
12	16- 5-1978	24	.03	.08	.00
13	17- 5-1978	12	.00	.08	.00
14	17- 5-1978	24	.00	.08	.00
15	18- 5-1978	12	.18	.08	.00

Precipitation: The amount of precipitation falling as rain or snow.

   Note: In [mm/hour] !

Evapotranspiration: Potential evapotranspiration. Evapotranspiration demands are at first attempted to be met at the potential rate from the surface storage. If the moisture content in the surface storage is less than these requirements, the remaining fraction is assumed to be withdrawn by root activity from the lower zone storage at an actual rate, proportional to the relative water content in the lower zone storage.

   Note: In [mm/hour] !

Temperature: Temperature data are only necessary when the snow routine is included (see: NAM parameters page 2).

Press F10 for more timesteps.
Press F5 for the next subcatchment.

> **Edit Menu Option 5:**

WATSYS NAM-BAME Connection

NAM Subcatchment		BAME Node
1	----->	6
2	----->	7
3	----->	2
4	----->	1
5	----->	3
6	----->	4
7	----->	8
8	----->	9
9	----->	21
10	----->	23
11	----->	5
12	----->	10
13	----->	11

F1Help F2Undo

EscExit

The routed runoff from the catchments of the NAM model is directed into the specified BAME node.

The BAME model may also be fed by other sources than the subcatchments of the NAM model. Any other input is specified in the 'inflow series', option 9 of the edit menu. Note: The type of input is to be specified also in option 7 ('Node Characteristics') of the edit menu.

WATSYS BAME Basic Model Data

NODES

Number of Nodes in the River Network (max.=30)	30
Number of Entering Nodes	11

SIMULATION PARAMETERS

Time Constant for Simulation Model [s]	86400
Number of Linear Reservoirs in the (Nash) Cascade	1
Reservoir Storage Constant of the Linear Reservoir Cascade	.750
Admissible Error in the Hydrograph Volume Balance	100.000
Auxiliary Variable to Terminate Iteration for	
Determining the Optimal Reservoir Release	.050
Auxiliary Variable to Determine the System Function	.050

NODES: The water is routed from high numbered nodes to lower numbered ones. Bifurcations can not occur. Use two nodes for indicating a reservoir, so you can evaluate the effect of the reservoir more precise.

Entering nodes: Nodes that represent the origin of a channel. These nodes have the lowest numbers. (So if there are 4 entering nodes, these are numbered 1, 2, 3 and 4.)

Time constant for simulation model: The length of the time steps used, so use the same length here as in the NAM model. Note: Here in [s]. Time steps of 24 hours are required for correct use of conservation reservoirs.
    Remark: For calculating of the NAM model only, make this variable zero!

Two ways of routing flow are possible: 1. Nash cascades and 2. linear reservoir

1. Nash cascades:

Number of linear reservoirs in the cascade: Flow is routed by Nash cascades (see manual). Enter here the number of reservoirs in the cascade (n).

Reservoir storage constant: The time constant in the Nash cascades (k).

2. Linear reservoirs: Make the value of 'number of linear reservoirs ...' zero. The reservoir storage constant (k) is used for each reservoir, but this variable will be overruled by any separate k value for a channel entered in option 8 of the edit menu 'const. lin. res.'.

Admissible error.. and auxiliary variables: Variables for terminating calculations or iterations. Smaller values give more accurate results but will increase the calculation time.

WATSYS BAME Node Characteristics

Node	Input (0-3)	Control (1/0)	Reservoir (1/0)	Max.Stor. [10E6m3]	Rule Curve (0-2)	Pred.Con.Rel. Rule [m3/s]
1	2	1	0	.000	0	.000
2	2	0	0	.000	0	.000
3	2	0	0	.000	0	.000
4	2	1	0	.000	0	.000
5	2	0	0	.000	0	.000
6	2	0	0	.000	0	.000
7	2	0	0	.000	0	.000
8	2	1	0	.000	0	.000
9	2	1	0	.000	0	.000
10	2	0	0	.000	0	.000
11	2	0	1	.000	0	.000
12	0	1	0	.000	0	.000
13	0	0	1	.000	0	.000
14	0	0	0	.000	0	.000
15	0	0	0	.000	0	.000

Input: Input into the BAME model
          0=None
          1=Inflow only (see option 9 of the edit menu)
          2=NAM model input only (see option 5 of the edit menu)
          3=Both

Control: Enter 1 if you want simulated and observed data listed in the
          calculation output file.

Reservoir: Enter 1 if the node is a reservoir, else enter 0.

Max.Stor.: Maximum storage of the reservoir. Enter this value for each type
          of reservoir.

Rule Curve: The way the reservoir is to be operated (see manual).
> Flood control:
          0=Optimal Release Rule: Inflow Time Series are to be known in advance.
            Add. data: 'Max. Storage'.
          1=Predetermined Constant Release Rule: Keeps outflow on constant level
            Add. Data: 'Max. Storage' and 'Pred. Con. Rel. Rule.'
> Conservation:
          2=Conservation Reservoir Rule: Complex operation rule.
            Add. Data: Max. Storage and variables under option 0. of the edit menu.
            Note: Time Steps of 24 hours are required for correct operation.

Pred.Con.Rel.Rule: If you use rule 1, the predetermined constant release rule,
          enter the target release. (Strategy is to keep the outflow on this level.)

WATSYS BAME Interconnections

Interconnection (Nodes)	Routing (1/0)	Time Lag [time step]	Const.Lin.Res. [time step]	Convey.Cap.River [m3/s]
1 -> 13	1	.1	.0	.000
13 -> 17	1	.1	.0	.000
17 -> 18	1	.1	.0	.000
18 -> 19	1	.1	.0	.000
19 -> 21	1	.1	.0	.000
21 -> 22	1	.1	.0	.000
22 -> 23	0	.0	.0	.000
23 -> 25	0	.0	.0	.000
25 -> 30	0	.0	.0	.000
2 -> 12	1	.1	.0	.000
12 -> 13	0	.0	.0	.000
3 -> 18	1	.1	.0	.000
4 -> 20	1	.1	.0	.000
20 -> 21	1	.1	.0	.000
5 -> 26	0	.0	.0	.000

Interconnection: Enter which nodes are connected with each other.
Note: If you have to use more or less than the reserved spaced for assigning the interconnections, you made a mistake ! Use F3 for an schematic overview.

Routing: Enter 1 if the Nash cascades or the linear reservoirs are to be used for routing, else (e.g. a reservoir) enter 0.

Time Lag: Shifting the discharge wave between two nodes over a certain period of time.

Const.Lin.Res.: The time constant used for routing flow with help of linear reservoirs. Note: Not for Nash cascades, see option 6 of the edit menu Usage: Option 6: Number of .. = 0; If a value is entered for option 6: Reservoir storage.. this value is used as a default, that will be overruled by a value entered here.

Convey.Cap.River: At present a dummy variable

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> **Edit Menu Option 9:**

WATSYS BAME Inflow Series

Node 13   Type: Internal | 100 Time Steps of 12 hours

Step	Date	Hour	Inflow [m3/s]	Observed Stream Flow [m3/s]
16	18- 5-1978	24	.00	.00
17	19- 5-1978	12	.00	.00
18	19- 5-1978	24	.00	.00
19	20- 5-1978	12	.00	.00
20	20- 5-1978	24	.00	.00
21	21- 5-1978	12	.00	.00
22	21- 5-1978	24	.00	.00
23	22- 5-1978	12	.00	2.00
24	22- 5-1978	24	.00	5.00
25	23- 5-1978	12	.00	1.50
26	23- 5-1978	24	.00	1.00
27	24- 5-1978	12	.00	.00
28	24- 5-1978	24	.00	.00
29	25- 5-1978	12	.00	.00
30	25- 5-1978	24	.00	.00

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Inflow: Inflow time series, inflow into the BAME model from any other source than the NAM model. Note: Specify the type of input in option 7 of the edit menu !

Observed Stream Flow: For calibration purposes with help of hydrographs (main menu option 3) you may want to enter measured streamflow data for some nodes (when available). A node were observed stream flow data data is available is called a control node.

WATSYS BAME Conservation Reservoir Basics

Node 6	Page 1 of 3

RESERVOIR CHARACTERISTICS

Number of States of Characteristics Curve (max.= 30)	10
Minimum Storage of the Reservoir [10E6m3]	.500
Minimum Operating Level of the Reservoir [m]	50.00

INITIAL CONDITION

	Year Month Day
Calculation Start Date (equal for each Reservoir)	1989 8 1
Starting Storage of the Reservoir [10E6m3]	1.000

DEMANDS

Desired Demand [m3/s]	2.000
Required Demand [m3/s]	.500
Discounted Required Demand [0-1]	.700

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NOTE: THE CONSERVATION RESERVOIR ALGORITM ASSUMES TIME STEPS TO BE 24 HOURS!!

If you specified a node to be a conservation reservoir (option 7 of the edit menu) you have to specify the characteristics in these three pages.

Calculation start date: Start date of the calculation of the reservoir rule.
   Note: The demands are fulfilled (when possible) also before this date.

Minimum Operating level: No water is released when the reservoir level is below this. *

Desired Demand: is released when the reservoir level is between the Upper Limit Level and the Lower Limit Level.

Required Demand: is released when the reservoir level is between the Lower Limit Level and the Emergency Limit Lower Level.

Discounted Required Demand: Fraction of the Required Demand that is released when the reservoir level is below the Emergency Limit Lower Level.

Note: When the water level is higher than the Upper Limit Level the reservoir acts as a flood control reservoir. Releases are made to attempt to draw the water level down.

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WATSYS BAME Characteristics Curve for Conservation Reservoir

Node 6   Page 2 of 3

State	Storage [10E6m3]	Water Surface Area [km²]	Water Surface Level [m]
1	.500	.500	50.00
2	.500	.500	50.00
3	.500	.500	50.00
4	.500	.500	50.00
5	.500	.500	50.00
6	.600	.600	60.00
7	.700	.700	70.00
8	.800	.800	80.00
9	.900	.900	90.00
10	1.000	1.000	100.00

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Storage: Specify the storage of the reservoir for the concerning state.

Water Surface Area: The surface area of the reservoir.

Water Surface Level: Height of the water above a certain reference level.

WATSYS BAME Operation Rule Curve for Conservation Reservoir

Page 3 of 3

Node 6

Month	Evaporation Rate [mm/hr]	Upper Limit Level [m]	Lower Limit Level [m]	Emergency Lower Limit Level [m]
Jan.	.010	90.000	70.000	60.000
Feb.	.020	90.000	80.000	60.000
Mar.	.010	90.000	70.000	60.000
Apr.	.010	90.000	70.000	60.000
May	.010	80.000	70.000	60.000
Jun.	.010	70.000	70.000	60.000
Jul.	.010	70.000	70.000	60.000
Aug.	.010	70.000	70.000	60.000
Sep.	.010	70.000	70.000	60.000
Oct.	.010	80.000	70.000	60.000
Nov.	.010	80.000	70.000	60.000
Dec.	.010	90.000	70.000	60.000

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Scheme for the Conservation Reservoir Release Rule:

———————— Top of the Reservoir ————————

> Flood control Release

·············· Upper Limit Level ··············

> Desired Demand Release

·············· Lower Limit Level ··············

> Required Demand Release

·············· Emergency Lower Limit Level ··············

> Discounted Required Demand

·············· Minimum Operating Level ··············

> No Releases

/////////////// Bottom ///////////////////////////
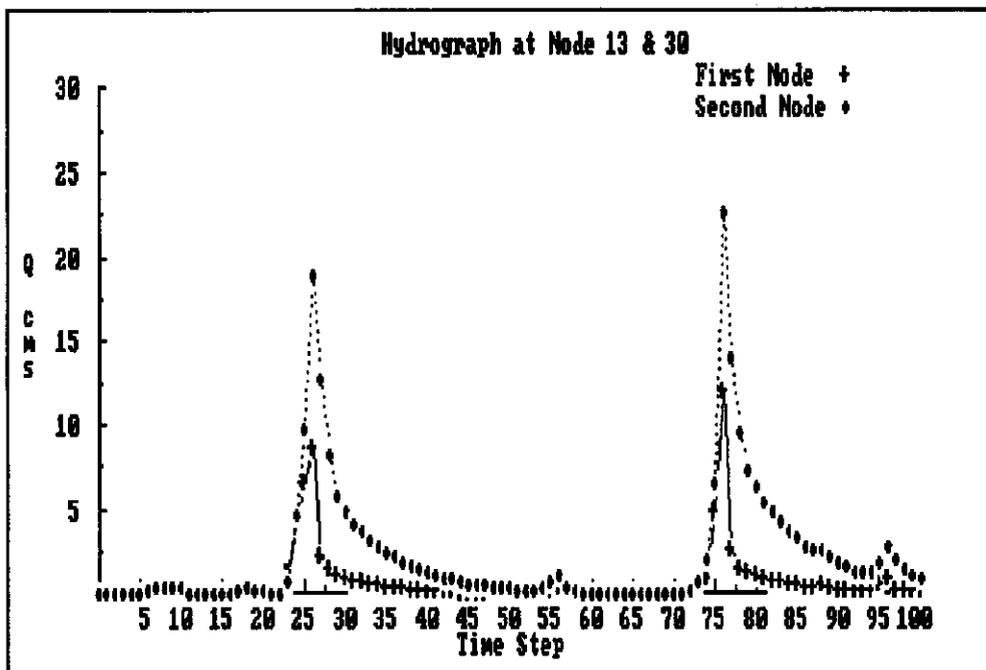
> Example of hydrograph of two different nodes.
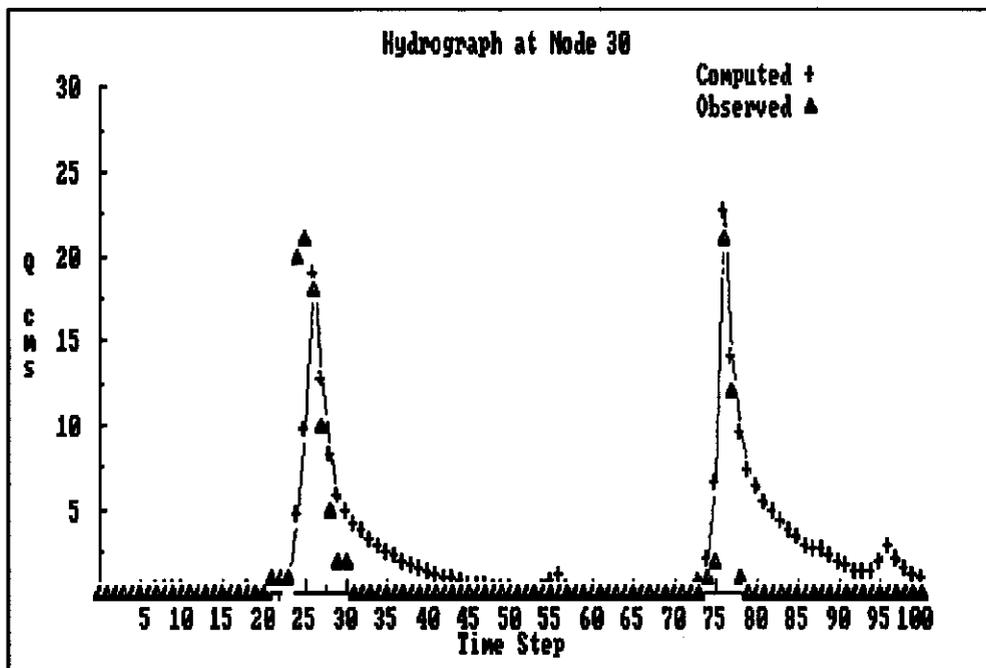
> Example of observed and calculated hydrograph.

APPENDIX IV   The Sulm Test Set

The Sulm is a river in Germany. The Sulm valley is about 20 km long and 7 km broad. The total catchment area is 122 km². In Mai and June 1978 two flood waves caused a lot of damage. A test set for WATSYS of this occurrence in the Sulm valley is available on your WATSYS diskette(s) (files: SULM.* in the directory TESTSET\). The values in the edit screens of Appendix II (except for the conservation reservoir pages) and the graphs in Appendix III correspond with this test set. An overview of the river network is given below.
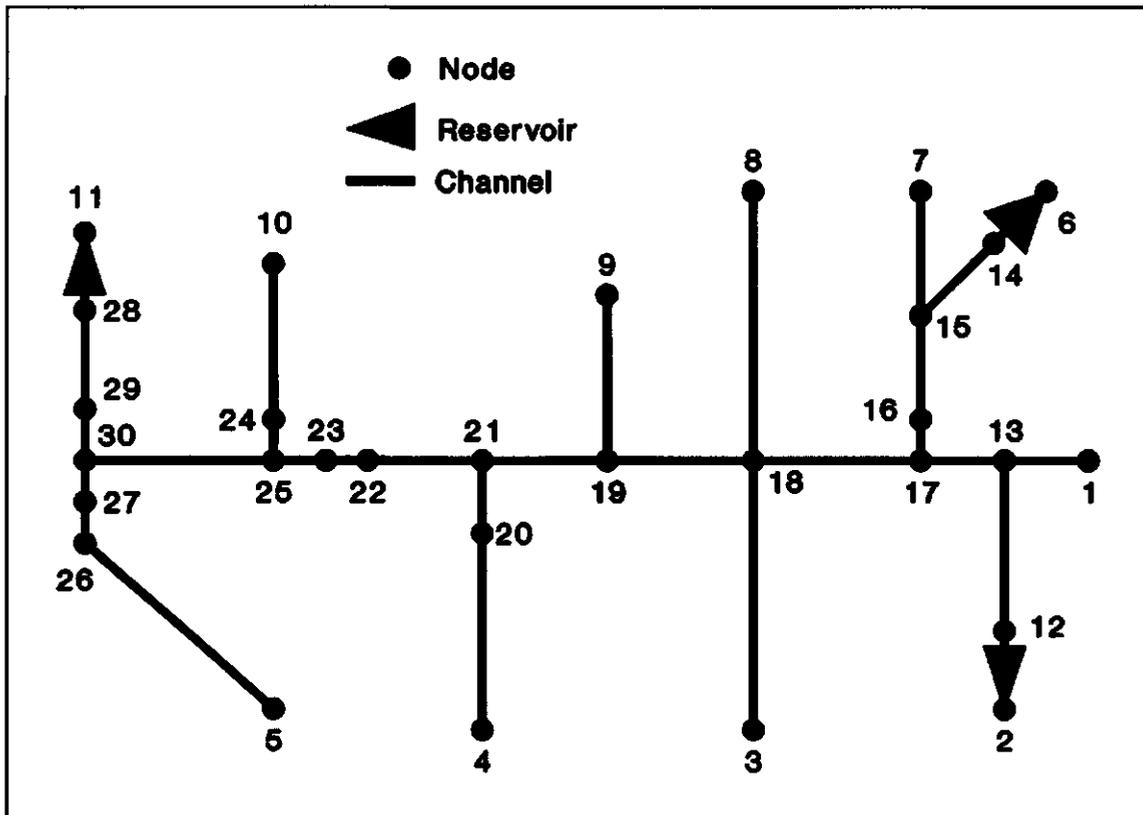
WATSYS network for the river Sulm (Germany).