

MIKE BASIN 2003

**A Versatile Decision Support Tool
For Integrated Water Resources
Management Planning**

**Guide to Getting Started
Tutorial**



CONTENTS

1	PREFACE	1
1.1	Copyright	1
1.2	Warranty	1
1.3	About this tutorial and user assistance.....	1
1.4	Hardware/software requirements	2
1.5	Installation.....	2
2	ABOUT RIVER BASIN MODELLING	3
2.1	About MIKE BASIN.....	3
2.2	Concept	4
2.3	Schematisation	6
2.4	Groundwater	6
2.5	Graphical User Interface.....	6
3	RUNNING MIKE BASIN.....	8
3.1	Examples and Exercises	8
3.2	Starting MIKE BASIN/ MILW	8
3.3	Creating a river network	9
3.4	Digitizing a river network manually.....	10
3.5	Adding and editing nodes and Making the Network.....	10
3.6	Allocation Algorithms	13
3.7	Node, Branch, and Catchment Properties.....	14
3.7.1	General.....	14
3.7.2	Connections between nodes.....	14
3.7.3	Local priority of connections.....	15
3.7.4	Copying properties	16
3.7.5	Time series in MIKE BASIN	16
3.7.6	Data-cycling in time series	17
3.7.7	Units in MIKE BASIN.....	18
3.7.8	Other tabular data in MIKE BASIN.....	18
3.8	Tools menu.....	18
3.9	Running a simulation	18
3.10	Examining Results	19
3.11	Closing a MIKE BASIN Project.....	22
3.12	Link to Excel / Optimization	22
4	WATER QUALITY SIMULATIONS	23
4.1	Conceptualization and Calibration.....	24



4.2 Summary of additional input for WQ simulations..... 24

5 RUNOFF, RAINFALL-RUNOFF MODELING 27

6 MIKE INFO LAND & WATER TOOLS 29

6.1 Land Classification..... 29

6.2 Import and Transform Tools 30

6.3 Surface Tools..... 30

6.4 Vector and Grid Tools..... 31

6.5 Sampling Point Tools..... 32

7 TIME SERIES EDITOR (TSEDIT) 33

7.1 Default time series files..... 34

1 PREFACE

1.1 Copyright

This document refers to proprietary computer software, which is protected by copyright. All rights are reserved. Copying or other reproduction of this tutorial or the related programmes is prohibited without prior written consent of DHI Water & Environment¹.

1.2 Warranty

The warranty given by DHI Water & Environment (DHI) is limited as specified in your Software License Agreement. The following should be noted: Because programmes are inherently complex and may not be completely free of errors, you are advised to validate your work. When using the programmes, you acknowledge that DHI has taken every care in the design of them. DHI shall not be responsible for any damages arising out of the use and application of the programmes and you shall satisfy yourself that the programmes provide satisfactory solutions by testing out sufficient examples.

1.3 About this tutorial and user assistance

This “Getting Started” tutorial is intended to give an overview of the MIKE BASIN river basin modelling software. The user is introduced to the concept of river basin modelling and how it is implemented in MIKE BASIN. The basic elements and features of MIKE BASIN are explained. After reading this tutorial, the user will *in principle* know how to use MIKE BASIN.

This guide, however, does not cover all capabilities at a detailed level. That level of user assistance is instead provided as on-line help as explained below. Hence, the novice user of MIKE BASIN is advised to read this document as an overview, and to build expertise by using MIKE BASIN and learning “as you go”. It is our experience that dividing documentation accordingly suits most users’ needs best. Furthermore, MIKE BASIN comes with its own step-by-step tutorial and example model set-ups.

Following the standards of Windows applications, MIKE BASIN utilises an integrated Online Help supplying descriptive information for every window. The Online Help supplies explanations on how to operate a specific dialogue as well as descriptions of the parameters present on the specific page. Context-specific on-line help is activated by pressing the “help” button” or the F1 key on dialog windows. The entire online help collection can also be accessed through the “help” menu item the MIKE BASIN main window. The online help also contains a step-by-step “Getting Started” section and various exercises.

Should you encounter any problems, please contact your local agent. In countries where no local agent is present you may contact DHI directly, by mail, phone, fax or e-mail:

¹ DHI is a private, non-profit research and consulting organisation providing a broad spectrum of services and technology in offshore, coastal, port, river, water resources, urban drainage and environmental engineering.



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If you wish to upgrade or purchase additional modules on an existing installation, please contact your local agent or DHI.

1.4 Hardware/software requirements

You need the following configuration for running MIKE BASIN:

- ArcView 3.2(a) or 3.3;
- Windows 98, NT, 2000, or XP;
- Minimum 64 Mbytes RAM recommended;
- High resolution monitor, minimum 800x600 pixels;
- Minimum 200 Mbytes free disk space.

1.5 Installation

All DHI software can be installed from the CD-ROM you received in your package (the installer starts automatically when you insert the CD-ROM). Note, however, that you must have installed ArcView before installing MIKE BASIN. There is no network license available for MIKE BASIN, so choose the “Local” option for license management.

2 ABOUT RIVER BASIN MODELLING

The rationale of undertaking water resources studies on a basin scale instead of on a project by project basis is based on the recognition that the water and land resources of a basin form a unity and hence must be treated as such if future conflicts over water utilisation are to be avoided.

River basin management and planning for a basin may broadly be conceived as an attempt to identify the best possible utilisation of the available water resources given certain soil, land, agricultural, engineering, and social constraints. Due to the multitude of water resources development options which often exist, conflicts over the utilisation of a particular source between individual schemes and the interdependency between water, soil, land use, and river basin management is indeed a complex task.

The planning for future water developments within a basin thus requires that conclusions originating from the study of particular aspects are gathered and brought together in a framework capable of undertaking an integrated analysis.

The water resources management tool MIKE BASIN, centred around a basin-wide representation of the water availability and potential users of water offers this framework.

2.1 About MIKE BASIN

In general terms MIKE BASIN is a mathematical representation of the river basin encompassing the configuration of the main rivers and their tributaries, the hydrology of the basin in space and time, existing—as well as potential—major schemes, and their various demands on water. Groundwater processes and resources are represented as well. The MIKE BASIN WQ module adds the capability to conduct water quality simulations.

MIKE BASIN is structured as a network model in which the rivers and their main tributaries are represented by a network consisting of branches and nodes. The branches represent individual stream sections while the nodes represent confluence, locations where certain water activities may occur or important locations where model results are required.

The mathematical concept in MIKE BASIN is to find stationary solutions for each time step. MIKE BASIN can be used to find "typical" values for water quantity and quality in a slowly changing system (e.g., the annual cycle of months). MIKE BASIN's advantage is its computational speed, allowing extensive albeit possibly approximate exploration of many scenarios. The approximation made in a stationary solution, however, becomes poor when the time-scale of a process is not less than the time step of the simulation. For fully dynamic problems, DHI Software offers the MIKE 11 modelling system.

MIKE BASIN is an extension to ArcView GIS, such that existing GIS information can be included in the water resources simulation. The network of rivers and nodes is also edited in ArcView.

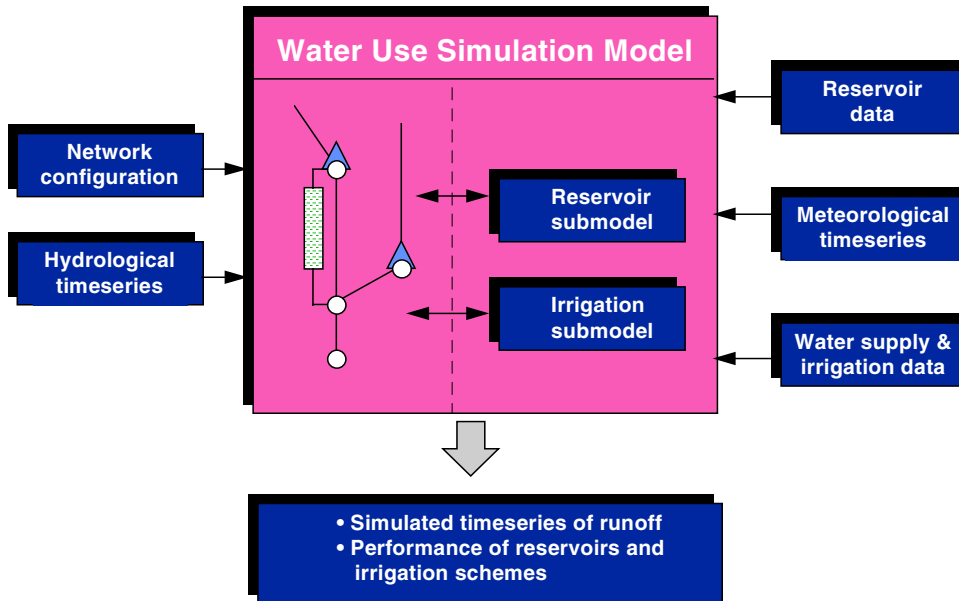


Figure 2-1 Concept of MIKE BASIN for water allocation modelling

2.2 Concept

The model operates on the basis of a 'digitised' river network established directly on the computer screen in ArcView™ GIS. All information regarding the configuration of the flow simulation network, location of water users, reservoirs and intakes and outlets of return flow are also defined by on-screen editing.

Basic input to the model consists of time series data of catchment run-off for each branch. Additional input files define reservoir characteristics and operation rules of each reservoir, meteorological time series, and data pertinent to each water supply or irrigation scheme such as diversion requirements and other information describing return flows.

Often, several users may want to receive water from the same resource. Within the MIKE BASIN network model concept, this situation is represented by several users connected to a single supply node.

In situations of water shortage, a conflict arises of how to distribute the water available at a supply node among the user nodes that are connected to it. A rule for resolving the distribution problem is required. MIKE BASIN can solve the water distribution problem for two types of priority rules, local and global. Local priority rules imply that the allocation problem is always solved for neighboring nodes that are connected directly. In a global scheme, in contrast, far-away nodes can matter as well. Global priority is typically used in river basins where users have prior rights, i.e., the right to water is determined by date of establishment. In those basins, upstream users often cannot exploit their geographical position.

In MIKE BASIN, the global priority algorithm is implemented by a set of rules. Different types of rules can be defined. Rules affect at least the node they are attached to, and possibly a second node, the extraction point of the former. Multiple rules can be associated with a single water user, not necessarily with consecutive priority ranks. For example, a user can have a high-priority rule for a necessary minimum supply, and a low-priority rule for additional supply. It would be perfectly legal

to have some medium-priority rules attached to other nodes that also affect flow at that user's extraction point. For a particular user, multiple rules can refer to either a single extraction point (node on the river) or to different ones. The global priority scheme does not account for delays in flow (routing, groundwater processes).

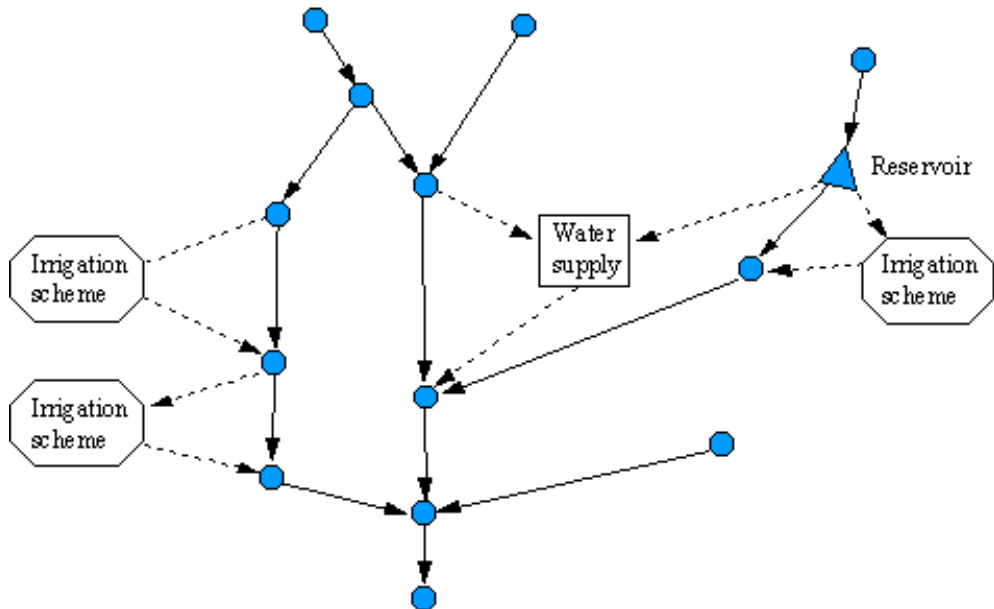


Figure 2-2 Schematic layout of network modelling

Within the local priority scheme, a strict priority is enforced for surface water. Supply nodes' dialog boxes allow for the specification of the sequence in which connected user nodes' water demands are fulfilled (see, e.g., the reservoir dialog). The first node in the list will receive its entire demand (if available) before the second node is considered. This second node will receive its entire demand (if available after the first node has received "its" water), and so on for the subsequent nodes. Any remaining water is flushed to a simple downstream node or, in the absence of such a node, assumed to leave the model area. For groundwater, all users have the same priority. They all receive the same proportion of their demand.

The overall modeling concept in MIKE BASIN is to find stationary solutions for each time step. Accordingly, time series input and output are presumed to contain flux-averaged values for a period between two time stamps, not pulses at a time stamp.

The approximation made in a stationary solution becomes poor when the time-scale of a process is not less than the time step of the simulation. A typical example where small time steps are required is reservoir simulation, particularly hydropower. The power generated depends on the water level in the reservoir, so if that level changes much during a time step, calculation results become poor approximations.

Due to the stationarity assumption, MIKE BASIN is best used to find "typical" values for water quantity and quality in a slowly changing system. For fully dynamic problems, DHI Software (<http://www.dhisoftware.com>) offers the Mike 11 modeling system. MIKE BASIN's advantage are its moderate data requirement (e.g., no river cross-sections) and its computational speed, allowing extensive exploration of many scenarios.

2.3 Schematisation

Before starting the model development it is recommended to define the appropriate schematisation of the river basin and the characteristics to be included. The evaluation of water resources in large river basins requires the incorporation of numerous individual demands and features. For example, a large number of small irrigation users are typically scattered in an area. To incorporate all these entities as individual schemes would in most cases require enormous resources.

It is therefore important in the model development phase to define a flexible schematisation reflecting the overall natural conditions and based on the objectives of the modelling, the availability of information and the spatial resolution of output data required.

Different types of spatial schematisation may be introduced:

- Lumping of smaller rivers into a single branch upstream of an intake point;
- Lumping of small irrigation areas into a single scheme with one intake point;
- Lumping town supply and industrial water supply into one entity.

The schematisation should represent the activities at the level of detail that is desired, while at the same time lumping homogeneous demands and resources for which no further differentiation is required.

MIKE BASIN also provides flexibility in specifying the simulation time step. Users can specify time steps in terms of days or months. An important consideration is to select an appropriate time step based on required temporal resolution of input data and results. For large models the computation time and storage requirements can increase significantly when reducing the time step.

2.4 Groundwater

Groundwater processes can be added to the default surface water simulation by checking the corresponding field in the properties dialog box. The specific runoff attributes dialog and the catchment (and offtake) node attributes dialog then have an additional tab “groundwater” for specification of groundwater-relevant information.

- stream seepage (river to aquifer; catchment node dialog (valid for upstream branch))
- groundwater recharge (catchment to aquifer; specific runoff dialog)
- groundwater discharge (aquifer to river; catchment dialog)

While the first two must be specified by the user (as time series), groundwater discharge is a hydraulic response and as such computed within MIKE BASIN. The underlying conceptual hydraulic model of an aquifer is the linear reservoir model.

Groundwater users (water supplies, irrigation) can also impact the behaviour of the linear reservoir by pumping. With the groundwater option enabled, groundwater resources thus become limited. See the online help for more detail.

2.5 Graphical User Interface

MIKE BASIN uses a graphical user interface (GUI), which links the MIKE BASIN computational engine with ArcView™ GIS. As an add-on MIKE BASIN can include additional GIS tools for data import/export, time series management, contouring, etc. These tools are available as the MIKE INFO Land & Water (MILW) module. MIKE BASIN can use results from MILW tools, but is not dependent on them. Integration within the ArcView environment ensures that the full ArcView

functionality is maintained. Because some of the MIKE BASIN interface functions use standard ArcView facilities the user should be familiar with ArcView. For general ArcView help refer to the ArcView Users Guide and the ArcView on-line help.

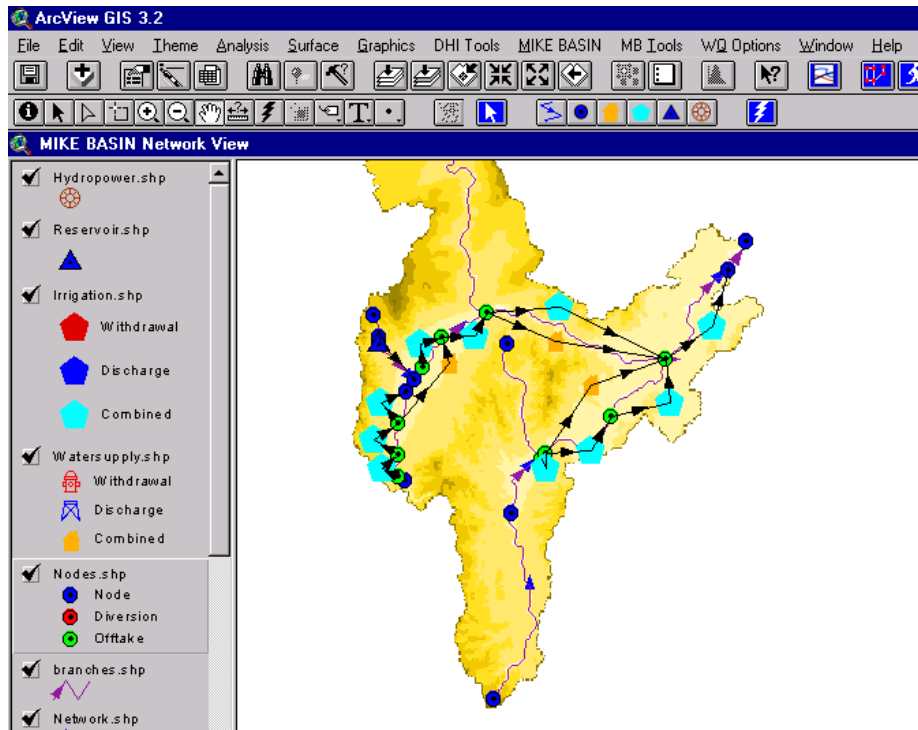


Figure 2-3. The MIKE BASIN / ArcView User Interface.

3 RUNNING MIKE BASIN

3.1 Examples and Exercises

Some example MIKE BASIN set-ups demonstrating typical applications are part of the installation. You can use those examples to familiarize yourself with the software, but you can also use them as starting points for real projects. Start the example from the Windows Start menu -> Programs -> MIKE BASIN & MILW <your version> Examples. In that menu, you can find an html document describing the particular examples.

A set of exercises that give a step-by-step introduction to MIKE BASIN are available from the MIKE BASIN homepage, www.dhisoftware.com/mikebasin, see Support.

3.2 Starting MIKE BASIN/ MILW

MIKE BASIN and the MIKE INFO Land & Water (MILW) suite of GIS tools for water resources are started through the Windows Start menu -> Programs -> MIKE BASIN & MILW <your version> -> MIKE BASIN & MILW. This action starts ArcView GIS, followed by the startup dialog.

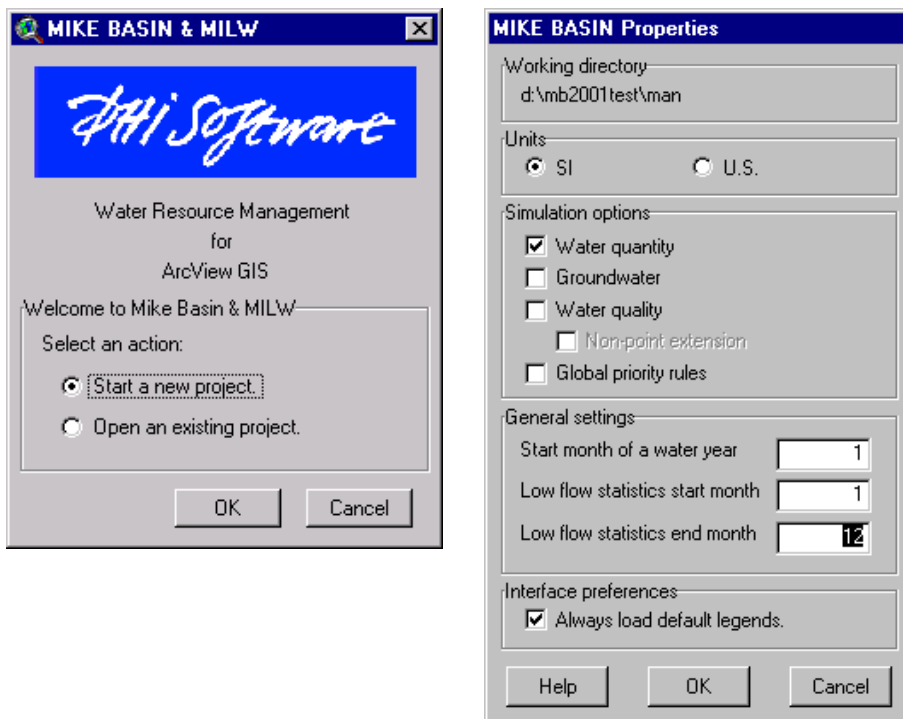


Figure 3-1. Setup (left) and Settings (right) dialogs.

You can now either specify a project directory for a new project or open an existing project. The project is an ArcView *.apr file which also includes all necessary MIKE BASIN information. Note that unlike in standard ArcView, MIKE BASIN lets you move or rename project directories after

they are created. This is possible because MIKE BASIN uses relative pathnames within a project (you can also have sub-directories in a project directory). After you click OK, MIKE BASIN and all MILW tools for which you have a license get loaded.

General settings can be accessed in the MIKE BASIN properties dialog. The user can choose between SI units and US units. All subsequent input and output will by default be in the type of unit specified. The default units cannot be changed if an existing scenario is opened, but units can be modified in the time series editor (see separate section in the manual). The user can include extensions and add-on modules available for his or her version of MIKE BASIN. The groundwater extension is part of the base version. It is possible, e.g., to first build a model for water quantity only, and then to add groundwater and/or water quality at a later stage. Start/end months for the monthly table output can also be specified (1 is January, and so on). Finally, the user can replace MIKE BASIN's default theme legends (as appear in the ArcView Table of Contents) by his/her own and choose to have those loaded.

3.3 Creating a river network

The river network for a MIKE BASIN model can be generated in two ways:

- 1) From catchment delineation (another MIKE INFO tool), using a Digital Elevation Model (DEM) and yielding a detailed to-scale network. For details, please see the online help or go through the exercises.
- 2) From manually digitizing a network, yielding a schematic network. This step is explained below.

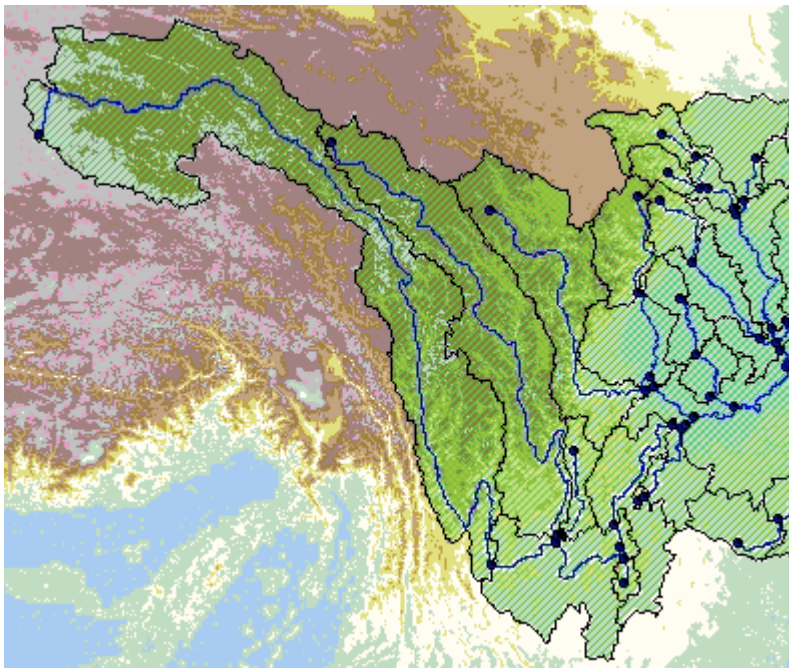


Figure 3-2. Detailed network based on a Digital Elevation Model (grid data).

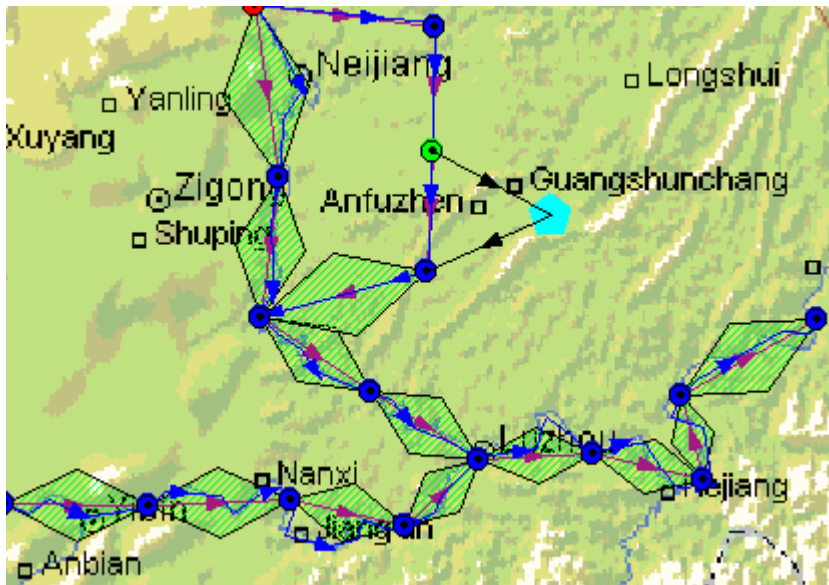


Figure 3-3. Schematic network with background map image.

3.4 Digitizing a river network manually

The user can digitize a network either based on an image (see Fig. XXX3), which illustrates the natural river system, or simply use a blank screen. A background image can be loaded via the ArcView menu “View” | “Add Theme...” (select “Image data source”).

Start by clicking on the “River button”, the leftmost edit button:



Digitize by clicking with the left mouse button at the end of every leg, then moving the cursor to a new position. Individual river sections (a series of legs) are completed by double-clicking at the last point. Tributaries should have their last point located at a main river at the location of the confluence.

3.5 Adding and editing nodes and Making the Network

Regardless of how the river network was created, nodes are then added in two steps:

- 1) Nodes on the river, defining catchments and extraction/return flow points for water users. After step 1), the network has to be “made” (explained below).
- 2) Water users off the river, but connected to the river via the extraction/return flow points

Nodes are added by clicking on the corresponding button in the menu list and then clicking at the position in the View where that node is to be placed. They can be placed on or away from the river, depending on node type:



The edit buttons:

- 1) · River
- 2) · Node on river (placed on river)
- 3) · Water supply node (placed away from river)
- 4) · Irrigation node (placed away from river)
- 5) · Reservoir node (placed on top of Node on river)
- 6) · Hydropower node (placed away from river).

When building a new MIKE BASIN model, the user first has to place nodes on the river (the other buttons are grayed out; they become accessible after the next step, making the network.) Nodes on rivers are however placed automatically during catchment delineation – so if you have used the latter and do not want to place additional nodes, you can jump directly to the next step below.

Nodes are placed on the river network by clicking the left mouse button at the desired locations. It is important always to place a node at:

- The upstream end of any tributary;
- A confluence / a point where two separately digitized river section meet;
- A diversion point / a point where a river section splits up in two;
- The outlet of the river system;
- Locations of reservoirs (to be added later).

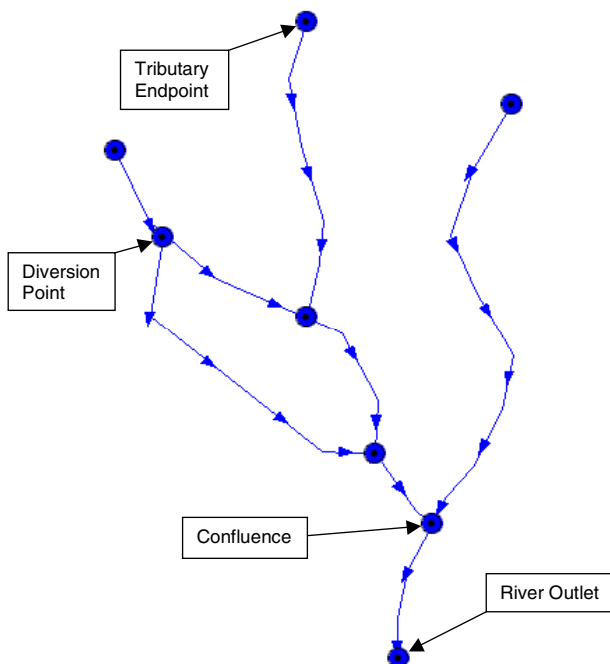


Figure 3-4 Locations where river nodes are always required

On the river network, two basic types of nodes are available, so-called catchment nodes and simple nodes. Catchment nodes are nodes which have an upstream sub-catchment area attached (i.e.,

representing the outlet of a sub-catchment). Simple nodes have no sub-catchment area attached (see here for details). When inserting nodes on the river network a dialog appears for specifying the type of node to be inserted. Note that the catchments will first be drawn after making the network.

The order in which the nodes are placed on the river network is not important. If a node is placed outside the digitized river network the nodes will automatically be moved to the nearest point found on river.

After step 1), the network has to be “made”. In this step, MIKE BASIN establishes the network topology. Furthermore, catchment areas upstream of catchment nodes are established and shown on the View. It is required to “make” the network every time new nodes are added to or deleted from the rivers.



To make the network, click on the Make button in the menu:

The first time “make” is performed, two new themes are created, called Runoff.shp and Branches.shp, which appear in the ArcView Table of Contents together with other themes. For schematic networks, the objects for Runoff.shp are in hatched green color (Fig XXX3). They are drawn on each branch that represents a sub-catchment area (the reach between two catchment nodes or the reach between a terminal up-stream node and a catchment node). In detailed networks as created using the catchment delineation tool, the true catchment areas are shown in hatched green (Fig XXX2). The Branches.shp theme represents the topological connections between nodes. In schematic networks, they are the straight-line connections between adjacent nodes, whereas in detailed networks, they coincide with the river network.

Nodes automatically take three different forms when “making” the network. A simple node can become either of the three forms, while a catchment node cannot be a diversion node. The possible combinations are:

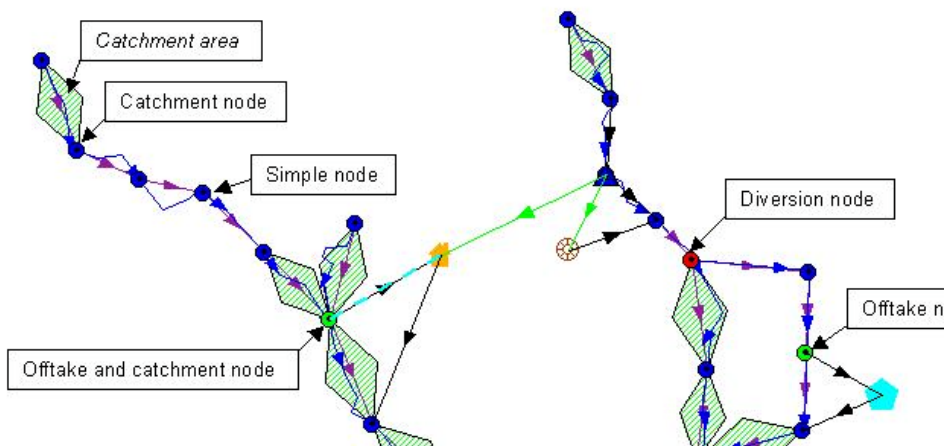


Figure 3-5 Forms of nodes

Simple and catchment nodes

Simple or catchment nodes on the river have only one downstream connection and no extraction attached. Several river branches can join at a simple node. Returning flow from water usage activities can be connected to a simple node.

Diversion node (on simple nodes)

A simple node becomes a diversion node when the river branch entering the node is split into two branches downstream of the node. For diversion nodes, specification of diversion conditions has to be assigned as that nodes' attributes. This is done by clicking on the node while the Network Dialog is in "Attributes" mode. See the online help for further details.

Offtake node

A simple or catchment node becomes an offtake node when off-take structures for irrigation or municipal and industrial water supplies are connected to it.

Other Nodes

User nodes (water supplies, irrigation, hydropower) can be placed anywhere in the View. Please refer to the on-line help for an in-depth explanation of how various types of user nodes can be specified with attributes. Reservoir nodes must be placed on top of nodes on the river (either simple or catchment nodes). Note that it is not required to "make" the network after user nodes have been inserted (because these are not on the river, they do not alter the network topology).

Nodes and branches can be renamed, deleted, or moved after they have been added to the model. To do any of the above, right-click on the object of interest, and hold down the right mouse button. A pull-down menu appears with all available edit options. (The pull-down menu also has other options, e.g., for display of results.)

3.6 Allocation Algorithms

MIKE BASIN can simulate allocation for two principles, local (default) and global priority. These are the two major principles of regional water laws. Local priorities are also called "riparian doctrine", global priorities "seniority doctrine", "prior appropriation doctrine", or "first in time, first in right principle".

Priority	Rule Type	Node 1:		Node 2:		Time Series File
		ID	Name	ID	Name	
1	ReservoirTargetLevelRule	R5	Ord River Dam			minlevelrule.dfs0
2	MinimumFlowRule	N12	Control Node			downstreamflowtarget.dfs0
3	ExtractionRule	R5	Ord River Dam	H1	Ord River Dam Hydr	
4	ExtractionRule	N3		I1	Current Irrigation	
5	ExtractionRule	N10		I5	Weaber Plain	
6	ExtractionRule	N9		I2	West Bank	
7	ExtractionRule	N3		I2	West Bank	
8	ExtractionRule	N6		I3	Mantina	
9	ExtractionRule	N13		I3	Mantina	
10	ExtractionRule	N14		I4	Carlton	
11	ReservoirTargetLevelRule	R5	Ord River Dam			ordreservoirtargetlevel.dfs0
12	ReservoirStorageRule	R5	Ord River Dam			

Figure 3-6. Global priority dialog example.

The allocation algorithm is chosen from the “MIKE BASIN” menu, “Settings”. There, you can check the “global priority rules” box to apply the global algorithm; uncheck the box to make MIKE BASIN revert back to the default local priority algorithm. You can view the rules already defined for this example set-up by choosing the “MIKE BASIN” menu, “priority rules”.

You can select a rule to edit it. At the same time, the relevant nodes will be highlighted in the View. There are different types of rules, affecting either a single node or a pair of nodes. Rules are applied in the order of priority, meaning that the higher the priority number, the less likely a rule is to be fulfilled. You can add and delete rules in the global priority dialog.

Note that when global priority is chosen, all demands specified in the local priority default set-up are ignored. Only users with an extraction rule attached are considered. Likewise, reservoir reduction levels are ignored as they only are defined for users immediately connected to the reservoir. Some other restrictions apply; for more information, please see the online help.

When using the local priority principle, you specify user priorities in the individual nodes’ dialogs. This is described in Section 3.7.3.

You can view the priorities (both local and global) using the command “view priority” in the “MB Tools” menu.

3.7 Node, Branch, and Catchment Properties

The various types of nodes, branches, and catchments require further specification of their characteristics. For example, water supply nodes require demand information, information on which nodes are used for withdrawal, and so on. All this information is called the properties of a feature.

Properties can be accessed in two ways:

1. Press the right-most edit button in the menu (the “lightning”), then click on the feature of



2. Right-click on the feature of interest (hold down the right mouse button) and select “Properties” in the pull-down menu that appears.

An alternative method of specifying properties is Table input. This method is fast, but does not use the View. To use it, choose the menu item “MIKE BASIN” | “Table input...”, which invokes a table with the attributes for all nodes (in the form used internally in MIKE BASIN, thus Input by Table should only be used by the advanced user).

Either method brings up a properties/attributes window for the particular node, catchment area, or branch. Several categories of information that the user has to specify are in common for all features. Often, default values are already shown in the relevant input fields, and default time series can be specified.

The types of input are described in the following.

3.7.1 General

The topmost part of attributes window covers general information such as the name and sub-type of the associated activity. Names are for easy identification by the user (they are optional).

3.7.2 Connections between nodes

Connections in the attributes window show how different activities are linked to each other. Connections must be specified both in the user’s attributes window and in the supplying node’s

attributes window in a consistent fashion. In other words, whenever a user is specified for a supply, that same supplier needs to be specified for that user. User connections are created by clicking on



the “**Select feature**” button. The relevant user nodes are selected in order of priority (see below for explanation) by selecting (*dragging the square around the node*) the nodes one by one while pressing the *shift key*. When the shift key is not pressed, each newly selected node will replace the previous one rather than be added to the list.

When a node has been selected in the above fashion, its ID code will appear in the “connections” field in the attributes window. The ID codes allow a concise representation of the connection and they are used internally, so the user need not be familiar with them. Suffice it to say that the codes’ first letter indicates the activity type, while the subsequent number indicates the sequence in which nodes were made part of the network.

In the example below, a pair of (partial) attribute windows are shown for a water supply and for a reservoir that are connected to each other (reservoir node R10 supplies water node W1).

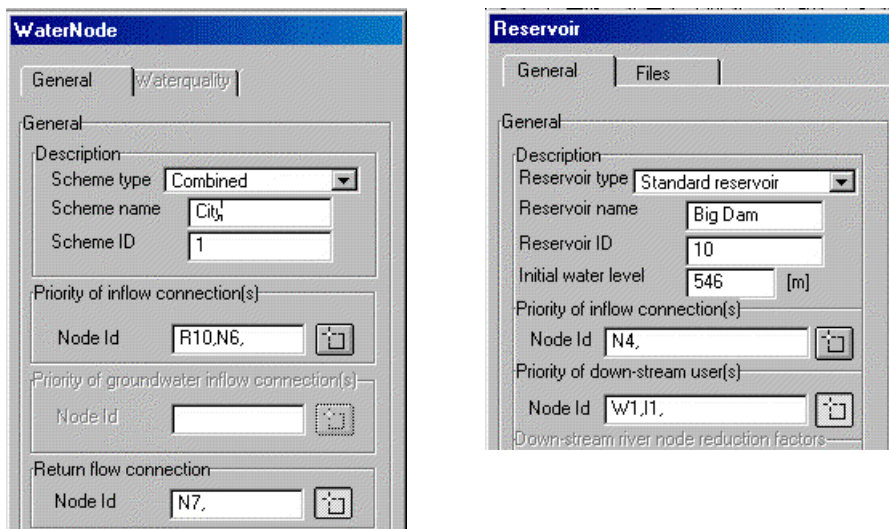


Figure 3-7 Attribute dialog boxes for water supply and reservoir themes

3.7.3 Local priority of connections

Another major principle to be aware of is how inflow and outflow priority is specified. Note that the following only applies when the local priority algorithm for solving the water allocation problem is chosen.

Within the local priority scheme, MIKE BASIN implements the principle that water available at nodes is distributed to downstream nodes in the order of a set priority sequence. This means that the first user in the list gets all its water demand (if possible), while the second user gets its demand only if enough water is left after the first user has received its water, and so forth for any other users in the list. Any remaining water is simply flushed along the downstream branch to the nearest node on the river. In the example in fig. 4.7 the reservoir has one inflow and two downstream users extracting water from the reservoir (“W1” and “I1”). The water supply (W1) has priority over the irrigation scheme (I2).

Particularly for a reservoir, the down-stream river node will automatically be connected and will always have the first priority. This connection is hidden for the user and cannot be changed. The

specified down-stream release to the river therefore always has priority over any other user. If a down-stream user needs to have first priority, the specified down-stream release for the reservoir must be zero.

In general, connections that do not have first priority are shown as green links on the screen.

3.7.4 Copying properties

Many dialogs in MIKE BASIN have a tool for fast model set-up by copying the input to other objects of the same time. The copying feature is available generally for normalized data. For example, runoff input in MIKE BASIN is generally per-unit area, so several adjacent catchments (with similar hydrologic characteristics) can use the same specific runoff time series. An example is shown below.



The “copy to selected features” facility is generally invoked by first checking the corresponding box, then selecting all objects that features are to be copied to. Copying includes all data that are enclosed by the rectangle on the dialog that also includes the checkbox. In the example, these are “Method”, “Runoff data”, and “Groundwater recharge data” (the latter is however disabled here). Copying takes effect when pressing the “Apply” or “OK” button. The user is generally prompted for confirmation.

3.7.5 Time series in MIKE BASIN

The input data required for most computations in MIKE BASIN are specified as a time series. Time series can be created and edited with the Time Series Editor that comes with MIKE BASIN and is explained in detail in its own Section in this tutorial. That input always follows the same principle with three choices / buttons:



- 1) the user can choose an existing time series by clicking on the “open file” icon to the right of the input field
- 2) the user can create a new time series by clicking on the “New” button. After a name is typed in the dialog that appears, a suitable default time series with all required items and “reasonable” values for all time steps is copied to the project directory (saved with the user-defined name).
- 3) the user can edit any specified time series file that appears in the input field by pressing the “Edit” button (this can be done after 2) above). The Time Series Editor (see separate section in this Guide) is then started when the user clicks on the Edit button, with a default file in the proper format for the particular kind of input. The user can then easily modify this series, save it, close the Time Series Editor window, and return to MIKE BASIN.

MIKE BASIN is very flexible in that it can use time series data with any time interval, or even with changing time intervals. Because most data are period-averages valid up to the subsequent time stamp, input time series must have a terminating line with one time stamp indicating the end time and all other columns empty, as in the example above. (In TSEdit, empty values are known as DELETE values). MIKE BASIN will give a warning if any non-DELETE values are found in the last line of a time series file and ignore any such values. DELETE values in rows other than the last one cause an error and will terminate the model run.

The most common data type is a period-average that is valid for the entire period starting with the time stamp in “its own” row up to the time stamp of the next row. Examples of period-average data are discharges, water demands, generated power, etc. A less common data type is a state, valid precisely at the time stamp of its own row. State data are mostly associated with reservoirs, e.g., water levels and storage volumes.

In the example of the preceding Figure, runoff is 1 l/s/km² from 01-07-81 to 01-01-82. A period-averaged value for the period of 01-06-81 to 01-08-81 would be $(30*2 + 31*1) / 61 = 1.49$, because there are 30 days in June and 31 days in July.

3.7.6 Data-cycling in time series

MIKE BASIN has a very useful feature called “**data-cycling**”. With this feature, it is possible to run MIKE BASIN for simulation periods for which some data are lacking, just as long as equivalent data are available for earlier or later periods. In these situations, data-cycling will find the closest possible equivalent time period in the data and use that period instead. For example, if a simulation is desired for the period of 01-01-95 to 01-07-95, but only the data in the preceding Figure were available, the runoff values for 01-01-81 to 01-07-81 would be used. When there are several years’ data in a time series, the first full annual cycle will be used for simulation periods earlier than that represented in the data, and the last one for periods later than in the data. This re-used annual cycle need not start with a January 1, but is generally the first time period covering a whole year in the data. Leap years are handled automatically.

As mentioned before, MIKE BASIN has a very flexible time handling scheme, so cycling is also possible for periods that are covered in the record, but for which time stamps do not exactly coincide with the desired ones. For example, one could simulate for the period 03-01-95 12:00:00 to 18-02-95 06:10:15 given the data in Table 1. Note that it is not possible to cycle when no equivalent periods exist in the data.

3.7.7 Units in MIKE BASIN

MIKE BASIN can handle data units in a very flexible manner. In TSEdit, the user can generally choose among several units for a given quantity. For example, specific runoff can be millimetres per second (mm/s), acre-feet per second per acre (ac-ft/sec/ac), or litre per second per square kilometre (l/s/km²). It is possible to mix U.S. and SI units in the same time series input file. To set units, choose the "Edit" menu in TSEdit, then "Properties".

On the output side, when creating a new MIKE BASIN scenario, the user can choose either among U.S. or SI units. MIKE BASIN then automatically uses the appropriate units.

3.7.8 Other tabular data in MIKE BASIN

The input defining the height-area-volume relationship for reservoirs and diversion tables are not time series, but are still edited in the Time Series Editor, as a table. The first item (column) is elevation/flow etc. (x) instead of time. Additional columns contain values corresponding to the x-values.

3.8 Tools menu

The "MB Tools" menu in the ArcView menu bar has a few helpful items:

Redraw

Redraw connections (to reflect updates on the network).

Priority labels

Show (or hide) the order of priority for up/down-stream connections for each scheme (e.g. reservoirs, irrigation, and water supply). The priority will be displayed numerically at each object, showing the order in which connections have been selected. The only exception is for reservoirs where the down-stream node connection always has first priority.

Check topology


Check whether all activities on the network are connected properly, i.e., whether specified user nodes exist and are connected to the proper offtake nodes.

Swap direction

If a river has been digitised in the wrong direction (down-stream -> up-stream direction) this tool will swap the direction to up-stream -> down-stream direction. This tool only affects rivers selected by the standard ArcView 'select feature' tools.

3.9 Running a simulation

The model set-up is finished after "making" the river network and specifying all input in the respective dialog boxes (you may want to check the topology also, see then Tools menu). Then, a simulation of water flow (and quality if the WQ module is installed) can be started by clicking on the

"running man" button. 

The execution dialog will appear. Please see the online help for documentation of required inputs such as start and end dates, output options, etc.

3.10 Examining Results

Model output comprises information on the performance of each individual reservoir (and associated hydropower units) and other schemes with water demands (irrigation, etc.). For the entire simulation period, the magnitude and frequency of any water shortages can thus be illustrated. Furthermore, time series of river flow at all nodes are simulated enabling the user to determine the combined impact of selected schemes on river flows.

Results can be viewed as time series for each node, or as snap-shots in time but overviews of the entire model area in ArcView. Scrolling through time, the user can create animations and see how the geographic picture of particular results (e.g., water shortage) evolves.

To access results at a node, just right-click it and choose “Time Series results”. TSEdit comes up with the results time series already loaded.

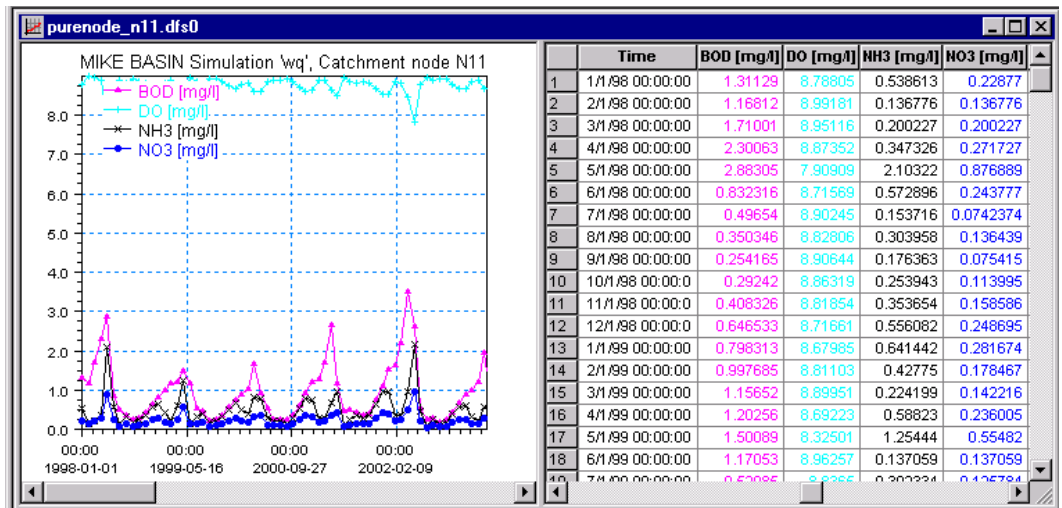


Figure 3-8. Time series results at a node, viewed in TSEdit.

If you have checked the corresponding option in the simulation dialog, you can also right-click at a node and choose “monthly table”. An HTML browser comes up with a summary table of monthly averages, low flow statistics, and links to neighboring nodes.

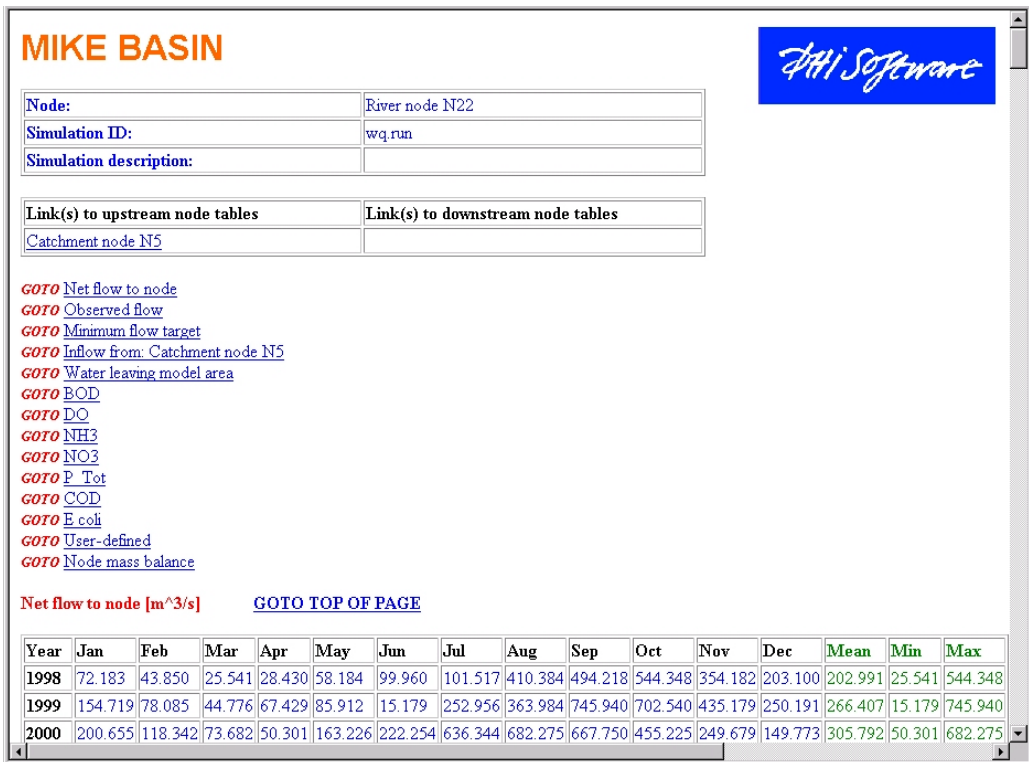


Figure 3-9 Monthly summary table output

To get a graphical display of results after a simulation in run, press one of two buttons in the menu:



The left button loads results that either can be accessed or displayed in the View (this step is not necessary if “automatically load results” option has been checked in the Simulation dialog).

You can scroll through time using a separate dialog, including running the presentation as an animation (see Figure 3.9). The animation can also be saved as an *.avi file that can be included, e.g., in PowerPoint presentations.



The right of the two results buttons loads the results database into Microsoft Access. The user can then execute queries and create reports or just execute one of the pre-defined ones (see Figure 3.10).

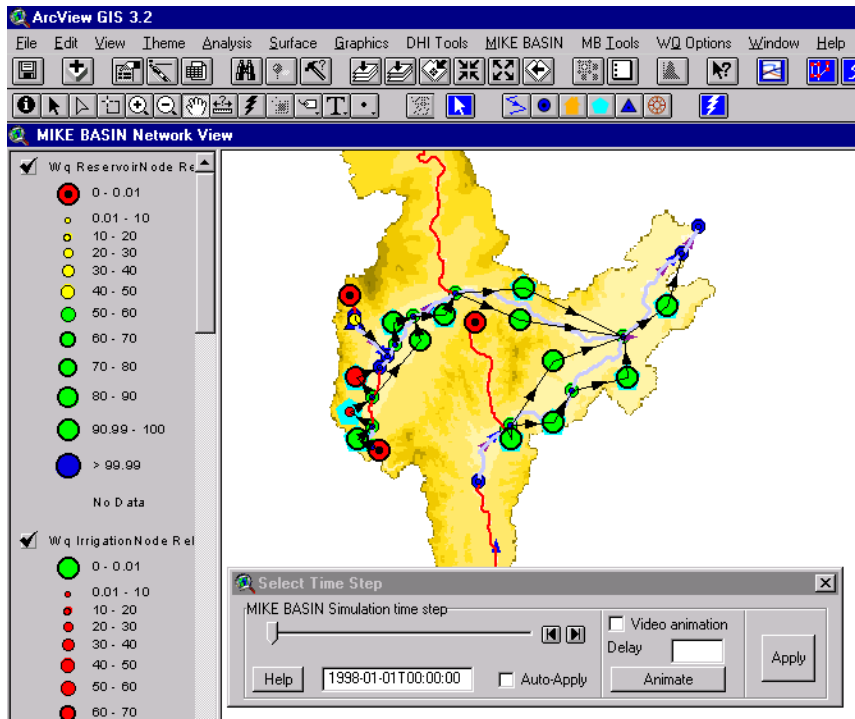


Figure 3-10. Graphical results presentation in the View.

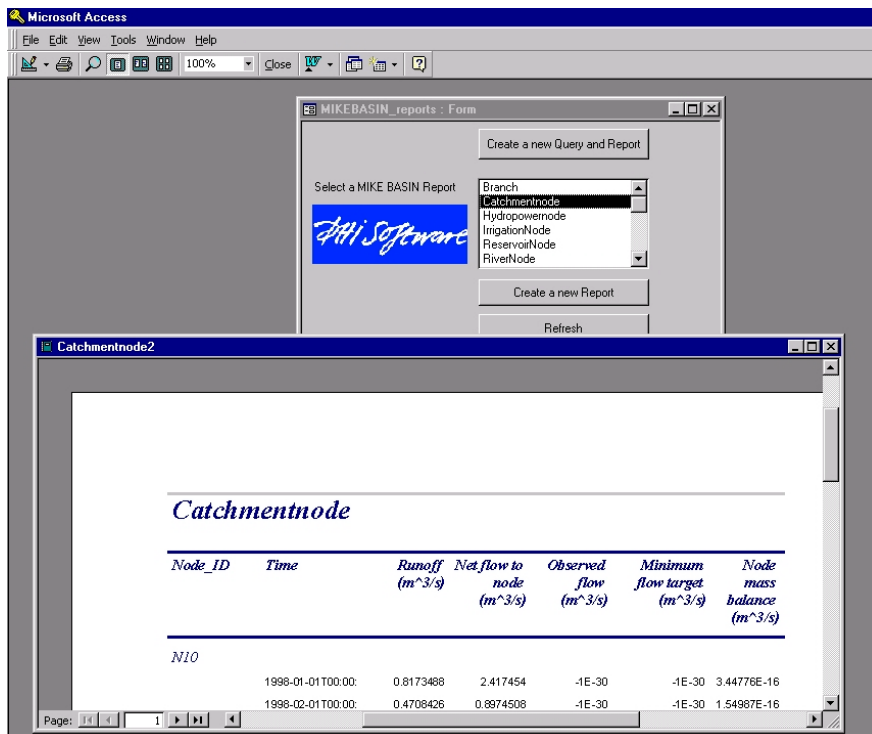


Figure 3-11 Using Microsoft Access to query the MIKE BASIN results database.

3.11 Closing a MIKE BASIN Project

On closing MIKE BASIN within ArcView, all information about the project can be stored on the disk, just like any other ArcView project.

3.12 Link to Excel / Optimization

After a regular simulation has run, the MIKE BASIN computational engine can also be accessed directly from Microsoft Excel. MIKE BASIN follows the COM standard, so one can create a MIKE BASIN object in a Visual Basic macro. In essence, such a macro automates the otherwise manual procedure of running a simulation

- 1) specify some input value in a time series
- 2) run the model (full simulation period or one time step at a time)
- 3) examine the results

This sequence is tedious to do by hand, especially if one wants to adjust some input in order to optimize some result. A typical example would be the adjustment of reservoir rule curve levels in order to increase hydropower production (or attain multiple objectives). When implemented in a macro, this sequence executes within a fraction of a second, and Excel's Solver tool can be used for the optimization.

The step-wise simulation offers essentially unlimited flexibility in implementing site-specific operation rules. One can see the previous time step's results and based on those update, e.g., water demands in the current time step. (Inter-basin) transfers can be modeled by virtual water users, extracting water from one basin and returning it in another, with demands getting adjusted dynamically as the simulation progresses.

The available macro commands for MIKE BASIN are described in detail in the online help. The installation also contains an example macro, which usually requires very little modification when used for another model set-up.

	A	B
1	input parameter	MIKE BASIN result (call from Excel)
2	Target for hydropower plant "Hydro1" [mwatt]	mean demand satisfaction for water supply "DemoVille" [%]
3	1	=MikeBasinEval(A3)
4	2	100.00

Figure 3-12. Excel interface (example).

4 WATER QUALITY SIMULATIONS

The WQ module (not included in MIKE BASIN's base version) allows water quality simulations. You can choose the WQ module from the Settings dialog, either when you start a new project or when you want to extend an existing water-quantity project with WQ processes.

MIKE BASIN WQ can simulate transport and degradation of the most important substances affecting water quality in rivers and reservoirs: ammonia/ammonium, nitrate, dissolved oxygen, total phosphorus, biological and chemical oxygen demands (BOD, COD), and E. coli. A wild-card substance can be used to represent an additional solute of interest in a particular study. Re-aeration from weirs and phosphate sedimentation in reservoirs are accounted for.

All transport is modeled as steady-state, as is in agreement with water movement simulations. With this simplification, numerical instabilities are avoided in MIKE BASIN. Transport/residence time in a branch can be specified either as a set value or via a rating curve (Q-h relationship). The calculation additionally requires the length and width of the branch, respectively. For reservoirs, residence time is computed as the ratio of volume and release (in a particular time step). Thus, the steady-state assumption can be poor for reservoirs with fluctuating releases.

The degradation process for some substances is described including reactive transformations (e.g., NH_4/NO_3 , DO / BOD). COD, E. coli, P_{tot} , and the wild-card substance are modeled as individual first-order decays. The user can specify all rate parameters (with 0 indicating conservative transport) or use default values. The same processes are modeled to occur in river branches and reservoirs, with additionally sedimentation of P_{tot} in reservoirs described by a Vollenweider expression. No decay is assumed to occur in simple connection branches between water users and the river system. Rate constants are adjusted for temperature following the Arrhenius principle (10°C increase in temperature gives double the rate). All rate constants are assumed to be valid for the entire set-up, as are any area-normalized oxygen fluxes to/from sediment and photosynthesis (those can be given as a time series).

Water quality can also be modeled for groundwater. Here, the linear reservoir model for the hydraulic description is combined with a continuously stirred tank reactor model for mixing. Transport in groundwater can be modeled as conservative or first-order decay. If there is any decay in the rootzone, the user should subtract it when assembling the required time series of mass fluxes by groundwater recharge. The mathematical solution is analytical and thus avoids numerical instabilities.

Initial conditions for the calculations are only required for storages of water. Recall that MIKE BASIN produces quasi-steady-state solutions for every time step, which corresponds to all branches being "flushed" in every time step. The only storages where water is accumulated between time steps are reservoirs and the linear reservoirs representing groundwater aquifers. For the storages, the user can specify initial conditions either as pristine (zero concentrations) or as those that result from a steady-state simulation given the first time step's inflows.

Point sources are generally water supplies with associated treatment plants. The user can specify treatment types and methods or choose from a list of pre-defined common ones, all of these representing concentrations in the effluent. Irrigation nodes cannot be used to specify point sources; non-point loads should be specified for catchments.

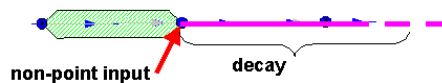
Non-point pollution includes NH_4 , NO_3 , E. coli, and P_{tot} . These are conveniently specified using the Load Calculator, accessible from every catchment nodes dialog ("WQ" tab). Several options for specifying loads are available

- Time series of concentrations (MIKE BASIN uses the corresponding runoff time series to calculate mass fluxes)
- Time series of mass fluxes
- The non-point module from MIKE BASIN 2001. This pre-processing tool overlays ArcView themes of landuse and population with the catchment theme in MIKE BASIN, finding the effective load for each catchment. Reduction factors representing decay within the catchment and treatment efficiencies can be specified
- The GIS-based DAISY model of crop production and soil water processes (available separately from DHI)

Each source, either concentration or mass flux, can be associated with a time series of calibration coefficients. Note that the time-weighted *average* of the coefficients in such a time series should be 1, *not* the sum (because the inputs are expressed as concentrations or rates and not as absolute amounts).

4.1 Conceptualization and Calibration

Because MIKE BASIN is a network model, inflow and extraction of water occurs only at nodes. Therefore, input of solutes also occurs at nodes. Particularly, this concept implies that non-point pollution from a catchment is modeled to enter a river only at the catchment node, along with runoff from that catchment. That solute input undergoes decay in all downstream branches, but not over the branch inside the catchment. This conceptualization is of course an approximation, but it is logical within the general node-and-branch concept of MIKE BASIN, where there is no intermediate inflow of water to a stream inside a catchment either.



The above-described conceptualization has to be kept in mind when calibrating water quality parameters in MIKE BASIN. If, say, you have concentration data at the catchment node indicated by the arrow, you cannot compare them directly to MIKE BASIN simulation results. Simulation results will generally be higher because none of the non-point pollution has undergone decay in the model, whereas in reality some pollution has entered the river upstream of the node location and undergone partial decay there. So to calibrate a MIKE BASIN WQ model, you can

- only compare concentration values at simple nodes, i.e., downstream of catchment nodes where non-point pollution enters the river network.
- work with small catchments such that non-point pollution inputs do not accumulate significantly before entering a stream
- subtract any known fraction of non-point pollution inputs to a catchment node (that in reality are decay in the connected catchment) before comparing simulated with measured concentrations at a catchment node

4.2 Summary of additional input for WQ simulations

To summarize the above description, here is a list of additional input data required for water quality simulation. For details on how to input these data, please see the online help.

- For the entire set-up: Rate coefficients at 20°C, yield and temperature coefficients, time series of temperature and oxygen fluxes to/from sediment.
- For every river branch: Either transport time and length, or rating curve and width. Total weir height and re-aeration coefficient.
- For every water supply: Effluent concentrations and time series of temporal variation coefficients
- For every reservoir: Vollenweider coefficient, type of initial condition.
- For every catchment: Nonpoint pollution (using one of the above 4 options). If running with groundwater: also time series of mass fluxes in groundwater recharge and type of initial condition.
- If calculating catchment mass fluxes with the Nonpoint calculator: ArcView theme with population, thereof with sewer connection and with connection to wastewater treatment. ArcView theme with number of pigs, cows, sheep, and chicken. Typical loads for each category, runoff coefficients for nonpoint agricultural loads, treatment efficiencies for human loads.

5 *RUNOFF, RAINFALL-RUNOFF MODELING*

MIKE BASIN lets the user specify runoff either as area-specific or absolute values in time series. With the MIKE BASIN RR module, the user can also generate these time series from rainfall and evaporation data. The MIKE BASIN RR module gives the user access to well-known rainfall-runoff models from MIKE 11, namely, NAM and SMAP.

Separate documentation on rainfall-runoff modeling is contained in the help directory of the installation (MIKE_BASIN_RR.pdf).

6 MIKE INFO LAND & WATER TOOLS

MIKE INFO Land & Water (MILW) is a series of tools which allow the user to manage spatial and temporal data for projects involving the comprehensive analysis of land and water systems (see table below). These tools are used within the ArcView GIS environment. This tutorial describes all tools, whereas details about their usage are described in MIKE BASIN's online help.

Land Classification	Tools for classifying terrain (elevation, slope, and aspect) of the land based on a digital elevation model, as well as tools to determine the start, end, and length of the growing season and frost risk over an area based on meteorological data. A wizard will overlay any number of criteria to create a final land classification (or land capability) map.
Import and Transform Tools	Allow the user to import various types of external data relevant for water resources assessments and administration (fArcInfo, Corine land cover data, Digital elevation models from US Geological Survey, MIKE 11 network files). Included is a tool for warping/georeferencing GRID (raster) data.
Sampling Point Tools	A number of tools for managing data on hydro-meteorological or water quality gauging stations in the GIS. The stations' time series data are stored in DHI's compact dfs0 format. Furthermore, the Sampling point tools provides link to the DIMS online monitoring database and access to a number of powerful time series processing tools. The latter allow the user to check, compare and make graphics of data directly from the GIS. Time series can be analysed and statistics extracted from a large number of stations and mapped. Rating curve calculations and extreme value analyses are also parts of the time series tools.
Catchment Delineation	Assists the user in generating catchment divides and catchment areas, flow paths and river network maps. Can be used closely integrated with MIKE BASIN.
Surface Tools	Used to generate grid surfaces from point information using various interpolation methods or to generate mean area weighing coefficients using the Thiessen or the Isohyetal method. Furthermore topographical profiles of along specified lines can be generated.
Vector and Grid Tools	A number of useful tools for manipulation and processing of shape and grid themes in ArcView.

6.1 Land Classification

The Land Classification Module of MIKE INFO Land & Water provides six tools for classifying and evaluating land. These include tools to classify the terrain (elevation, slope, and aspect) of the land based on a digital elevation model, as well as tools to determine the start, end, and length of the growing season and frost risk over an area based on meteorological data. (In addition to frost risk, the user may specify any other temperature criteria.) Finally, the Land Classification Wizard will

overlay any number of criteria to create a final land classification (or land capability) map. Land classification is not integrated with MIKE BASIN simulations.

6.2 Import and Transform Tools

When you have loaded the Import and Transform Tools into MIKE INFO Land & Water, a new menu is added to the View, called “Import and Transform”. It contains five choices. The first four are for importing various file formats into native ArcView shape files, and the final one is for georeferencing grids to match the coordinate system of other data.

Import and Transform Tools are not integrated with MIKE BASIN simulations. Digital Elevation Models are however used for catchment delineation, which can be used to rapidly generate a MIKE BASIN network for water quantity and quality simulations.

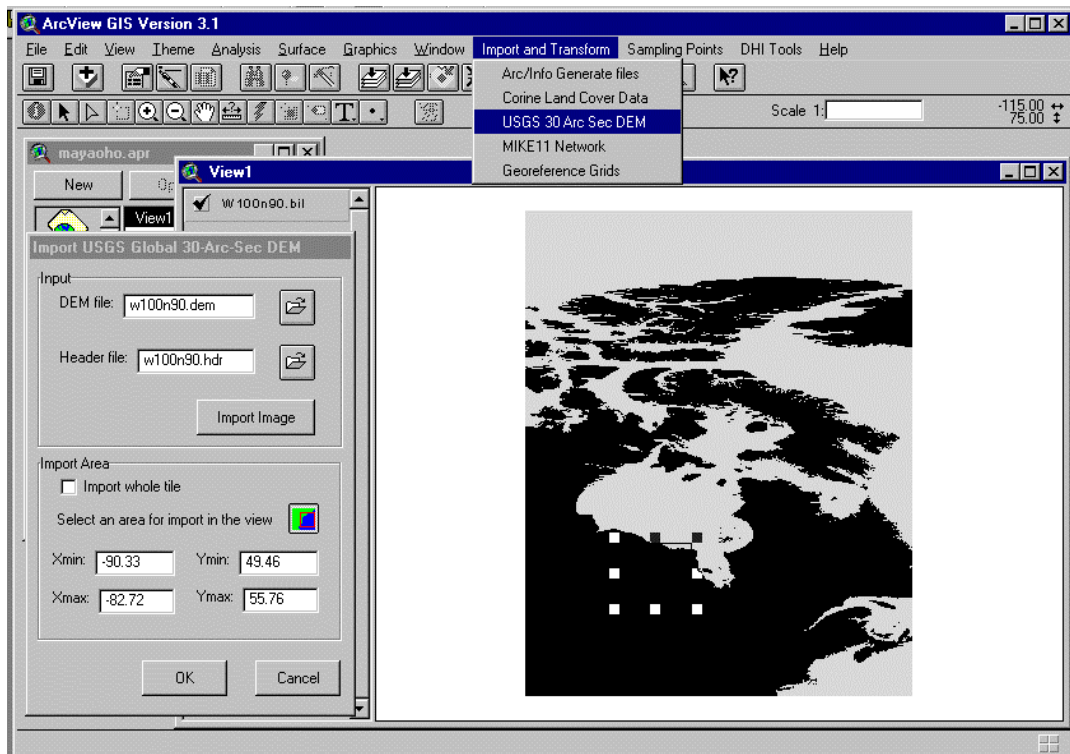


Figure 6-1. Importing a USGS DEM with the Import tool.

6.3 Surface Tools

The surface interpolator allows the user to interpolate surfaces from point themes. Four different methods are available (Inverse Distance Weighted, Spline, Kriging and Trend). A brief description of these are found in the ArcView GIS on-line help. The surfaces created from the interpolation are in ESRI grid format. The tool can be used for creating digital elevation models (DEM) from elevation points, rainfall surfaces from rainfall gauges, etc.

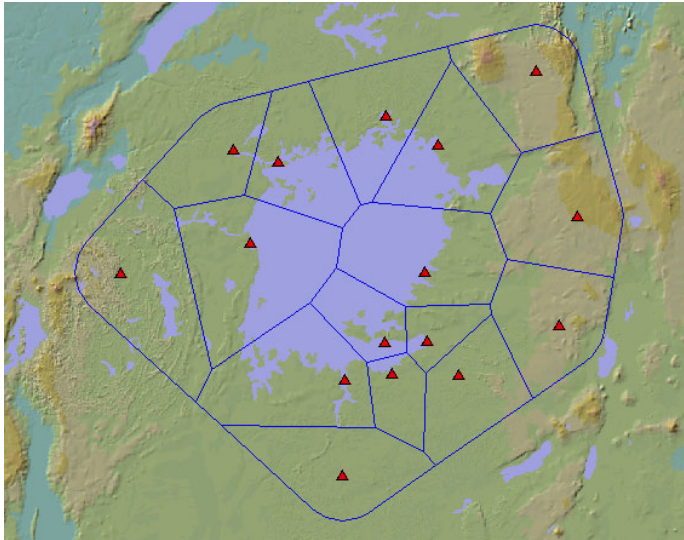


Figure 6-2. Thiessen polygons created with the surface tools.

6.4 Vector and Grid Tools

The vector and grid tools are a few simple tools which are part of the standard ArcView (and Spatial Analyst) products, but which do not have an easy-to-use interface in the standard GUI.

Shape File Tools

The shape file tools consist of two spatial editing tools, and one tool to calculate areas in polygons:

- **Merge Active Themes.** This tool will take the active themes in the table of contents and merge them into one. This is useful when you have tiled data where you have the same type of data from two different, but adjacent areas. For example, if you have main rivers and tributaries in separate themes you can merge them into one.
- **Dissolve Boundaries.** If you have a polygon theme with adjacent polygons that have the same value for a given attribute, you can use this button to dissolve (delete) the boundary between them. When selecting this tool, you will be asked to choose which field to use for dissolving. Any polygons with the same value in this field will be merged into one.
- **Calculate Areas.** ArcView does not automatically calculate areas for polygons. If you select this tool, a new area field will be added to the active theme with the area of the corresponding polygon. Note that this area is not automatically updated, so if you edit the shapes the area will be out of date. Just use this tool again to update the areas.

Edit Grid Tools

The grid tools consist of three tools for manipulating grids.

- **Fill DEM.** This performs the same function as in catchment delineation module.
- **Calculate Slope.** This will take the active grid theme (assuming it is a DEM) and calculate the slope. This differs from the standard Spatial Analyst function in that you can choose between slope in degrees or percent.
- **Clip Grid.** This tool lets you cut out a region of a grid. Once you've selected this tool, digitize a polygon surrounding your area of interest. Double click to stop. A new clipped DEM will then be added to the view.



6.5 Sampling Point Tools

The sampling point tools allow you to attach time series data to a point shapefile and analyze them from within ArcView. The time series data may be in one of two forms. They can either be extracted from the DIMS real-time database, or they can be *.dfs0 time-series documents as used in the Time Series Editor.

7 TIME SERIES EDITOR (TSEEDIT)

MIKE BASIN uses a time-series editor TSEdit (DHI software) for input of time-series data. Data can be imported into the editor from files with tab delimited ASCII or dfs0 file formats.

It is often useful to work in a spreadsheet program initially and then enter the data into the Time Series Editor from the spreadsheet using the standard windows cut and paste functions. If you prefer to work with a spreadsheet, you can copy the contents from the Time Series Editor into the spreadsheet and make modifications there.

Please note that the date format used in the Time Series Editor is always **yy-mm-dd hh:mm:ss**. Date type data from spreadsheets can be copied and pasted into the Time Series Editor.

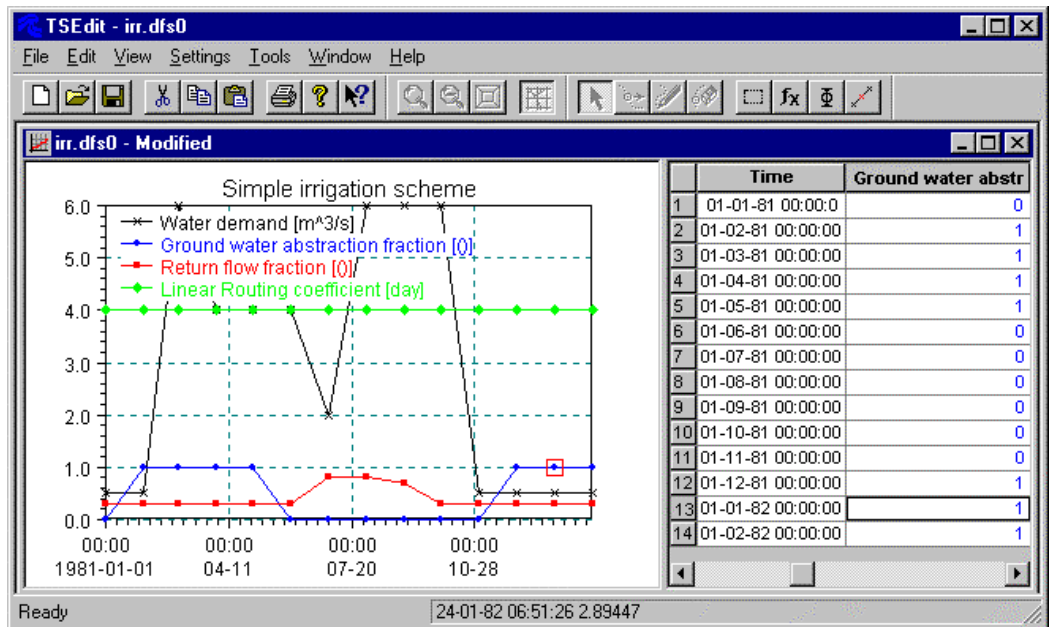


Figure 7-1 Time series editor

Two often-used dialogs should be learned:

Properties dialog:

The properties dialog is accessed from the Edit menu. In this dialog the type and units of the individual time series items can be defined. New columns can be inserted or appended. In general, changing the items in a time series is not often done in MIKE BASIN, because the “new” time series are always created from appropriate templates in which everything is defined as needed. The only exception are reservoir rule curves, for which the template is appropriate for up to 2 users with 2 reduction levels each. If a particular reservoir node has more users attached or more reduction levels per user, additional items have to be added (of the same type and unit as the existing ones).

The properties dialog also shows simple descriptive statistics for each item (min, max, mean). Scroll horizontally to the end of every line in the Item Information part to see this useful information.

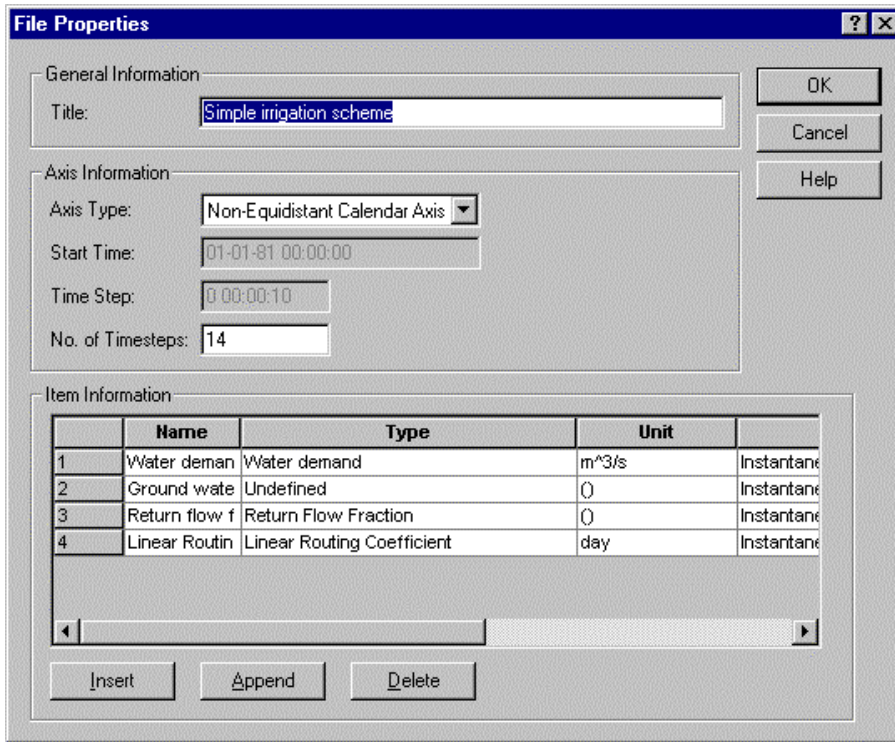
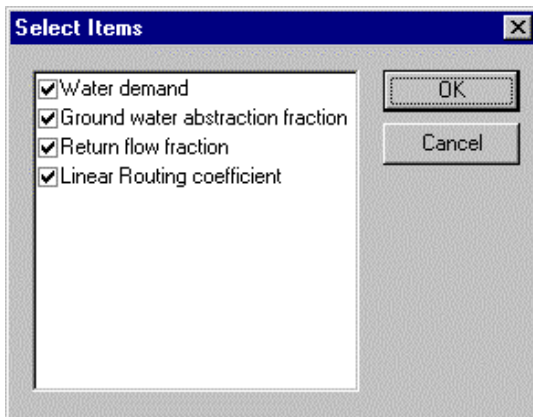


Figure 7-2 Properties dialog



Select Items

The Time Series Editor displays the data in tabular form and as graphs. The number of graphs to be displayed can be chosen in the Select Items dialog accessed by left-clicking in the graph window.

Figure 7-3 Selection of items to be displayed

7.1 Default time series files

The default files are located in the Setup directory. The file names are self-explanatory (e.g., “irrigation.dfs0” for an irrigation time series). Note that the ending “_US” indicates the U.S. units version of the default files. It is possible to modify the default files in the Setup directory if required. However, be sure not to change the file names.