HYDRONOMEAS

Version 4.0

Model for Simulation and Optimisation of Hydrosystems Management

User Manual

H Y D R O G A E A

HYDRONOMEAS

This software product is part of HYDROGAEA, a system of co-operating software applications, suitable for the Integrated Management of Water Resources.

The products of HYDROGAEA developed from the Department of the Water Resources of the National Technical University of Athens, in cooperation with NAMA Consulting Engineers and Planners SA and Marathon Data Systems.

HYDRONOMEAS

This user manual is published from:
Marathon Data Systems and NAMA Consulting Engineers & Planners SA

Athens February 2007

Editor *G. Karavokyros, A. Efstratiadis, I. Vazimas*

Contents

Part I

1 Introduction to Hydronomeas

1.1 General

HYDRONOMEAS is a comprehensive tool for the simulation and optimal management of water resource systems, incorporating a wide range of physical, functional, financial, administrative and environmental aspects of water. The software proposes management policies that minimize the operating cost and the risks regarding the quantitative and qualitative adequacy of water for every use. Results are shown in the form of tables and graphs, while simulations are dynamically visualized.

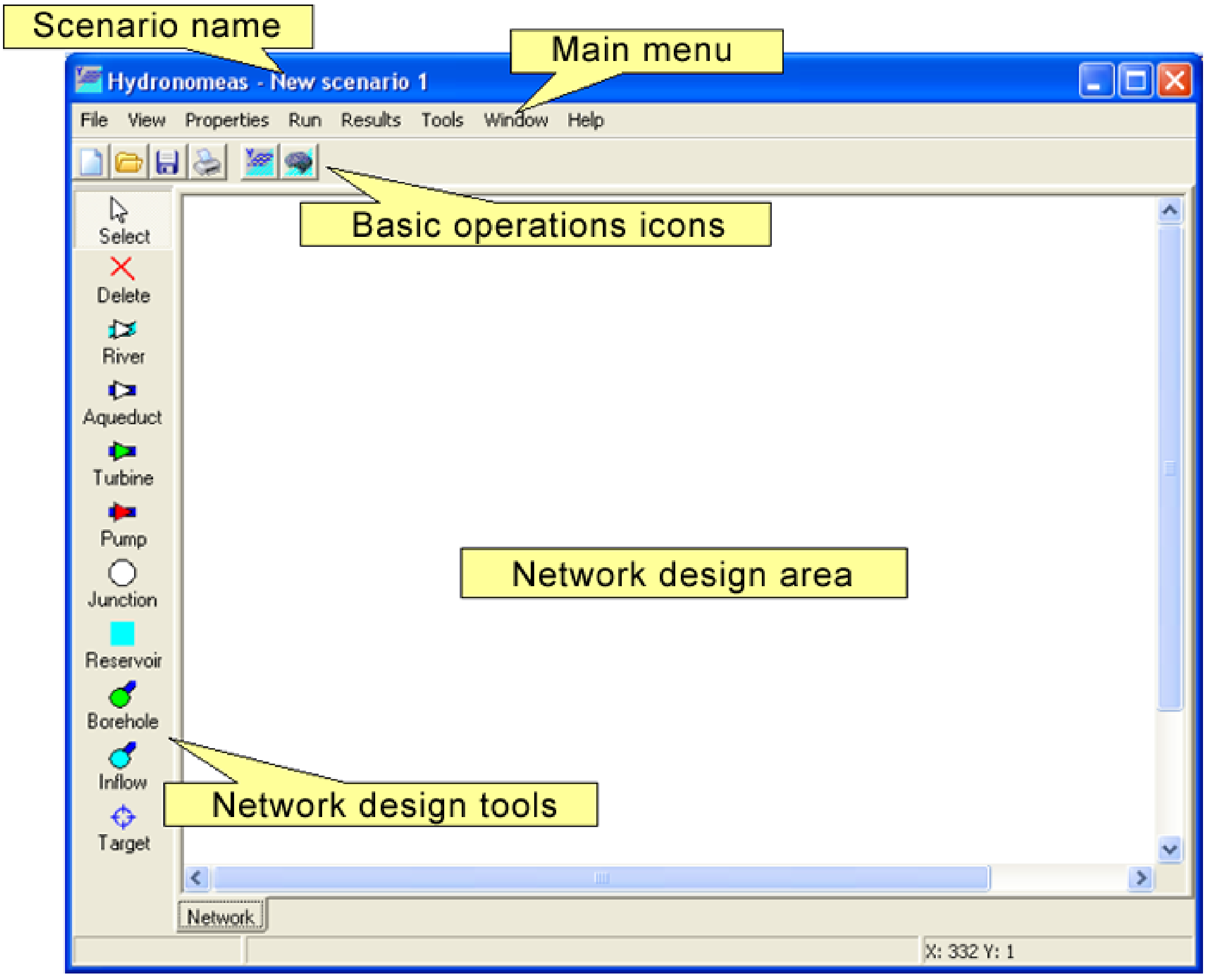
HYDRONOMEAS is able to provide answers to pertinent questions that concern water resources administrators, including the following:

- What is the maximum total withdrawal from the hydrosystem, given the hydrological regime and the reliability level for achieving targets (water supply, irrigation, hydroelectric power production, supply, etc.)?
- What is the minimum failure probability in achieving a given set of operational goals, for a given hydrologic regime? In which month/year is failure probability increased?
- What is the minimum cost to achieve a given set of operational goals, for a given hydrologic regime and a given reliability level?
- What is the maximum benefit from energy production?
- Which shall be the impact on results of the different administrative or climatic scenarios and any potential future modifications of the network?
- How could the system respond to special occasions such as channel damages or an intense increase of water demand for a specific period?
- What are the consequences of specific modifications in the hydrosystem (e.g., construction of new projects)

1.2 The desktop

Upon launching HYDRONOMEAS, the **Main Form** is displayed, which initially covers all the area of the screen and is comprised of:

- The main menu
- The main operations icons
- The network design area
- The network design tools



Provided that no scenario has been loaded in the database, a temporary **name** is given to the actual scenario which is displayed in the header of the form. The scenario will be given the final name determined by the user when saving the scenario in the database. Next to the scenario name, an asterisk (*) is displayed, if changes made to the scenario have not been saved yet.

The user can design the hydrosystem model using the **design tools** and the **network design area** that covers the greatest part of HYDRONOMEAS Main Form. Other operations, such as performing calculations and previewing results, are made either from the **main menu** or by selecting the relevant **icons**.

Exiting the application

You can exit the application

- By selecting **File/Exit** from the options menu. This will consecutively close all loaded scenarios.
- By closing the last loaded scenario.

Part II

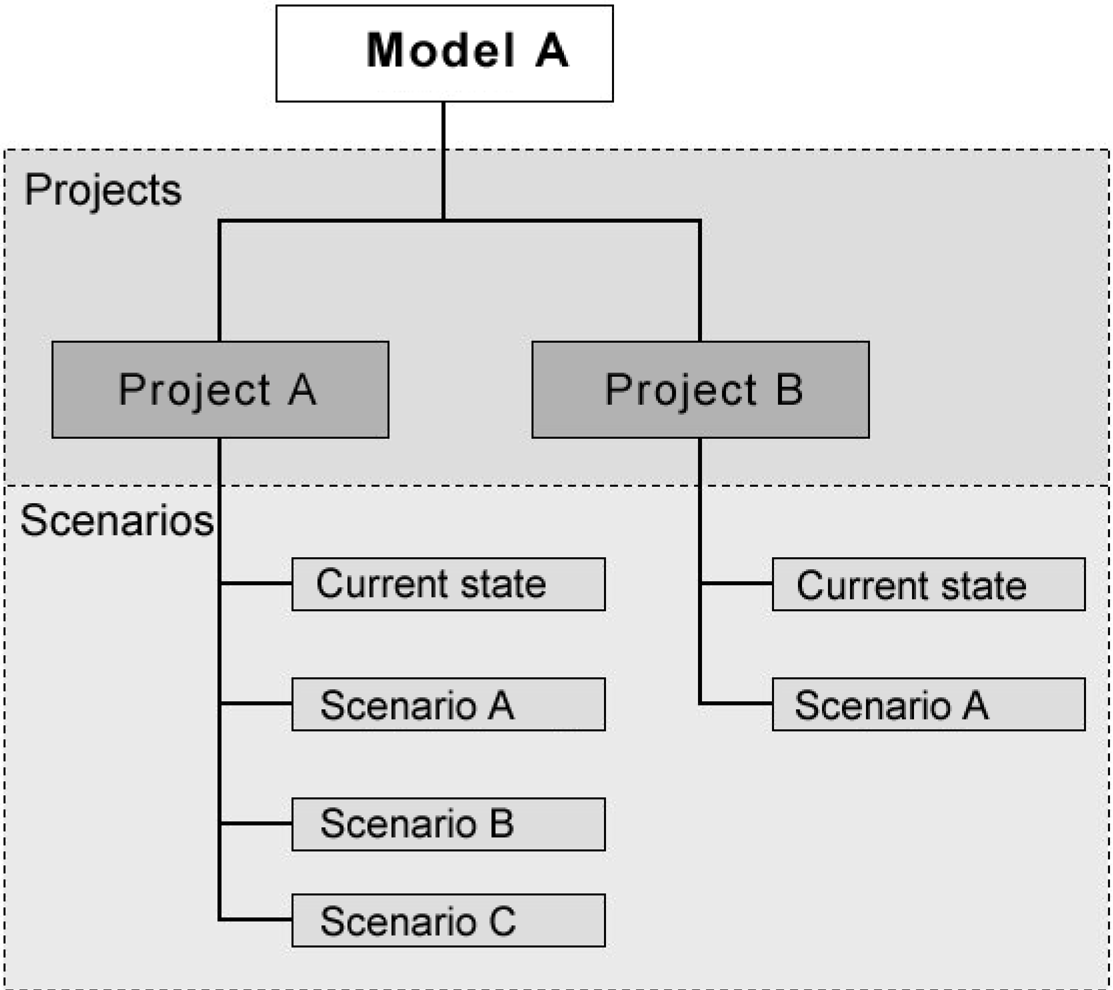
2 Managing Scenarios and Projects

2.1 Description of main concepts

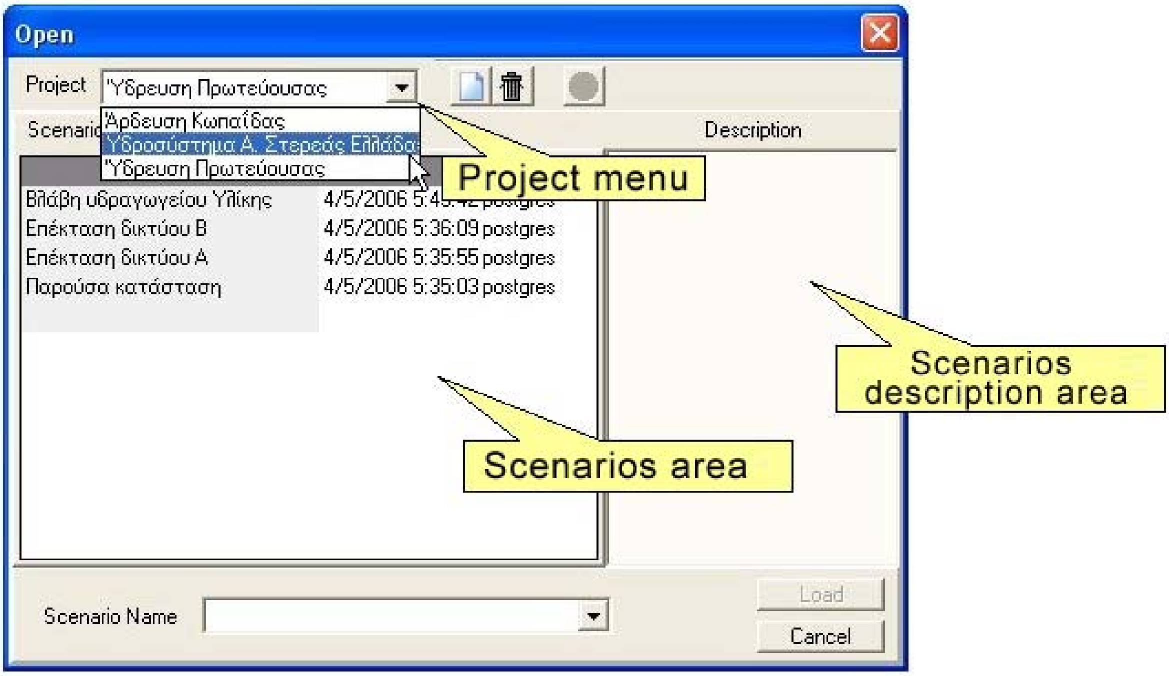
This **mathematical model** has been designed to be deployed within the framework of a technical **project** in the area of water resources management. The project may actually exist or may be the subject of a study. Within the framework of this project, a series of actual or hypothetical cases must be examined. We usually refer to such cases using the term **scenarios**, and we identify them in current state scenarios, failure scenarios, inflow forecast scenarios, etc.

In transposing this in the mathematical model, it is established that a scenario is nothing more than the total of input data used by the mathematical model. Such data are each time adjusted in order to respond to the respective state that corresponds to the scenario.

The database is able to manage multiple projects and scenarios of different mathematical models. A project in the database is identified by the name of the project (that may refer to a place) and by a short description.



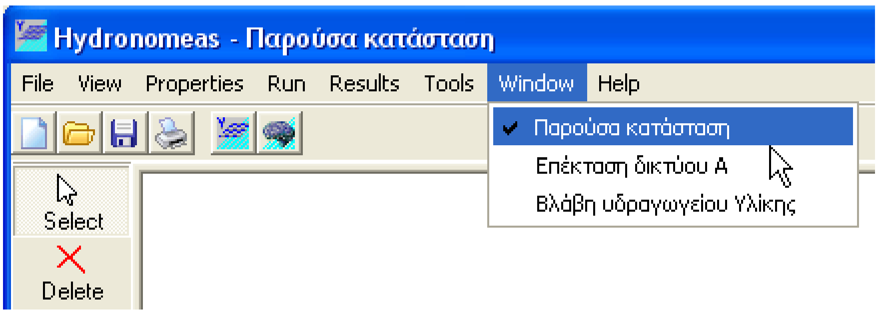
The access to scenarios and projects in the database is made through a dialog form. In such form, users can preview all projects and scenarios belonging to the mathematical model. In the top part of the form, we can see the **Project** drop-down menu. Clicking the right part of this menu, all model's projects shall appear. By selecting a model, all scenarios belonging to this project shall appear in the **Scenarios** area. By selecting a scenario, a short description of the scenario shall appear on the right part of the form **(Description)**, if such description exists in the database.



2.2 Actual scenario

HYDRONOMEAS can memorize more than one scenarios designed by the user or loaded from the database.The **actual scenario** is the one that the user is actually viewing and editing on the screen.

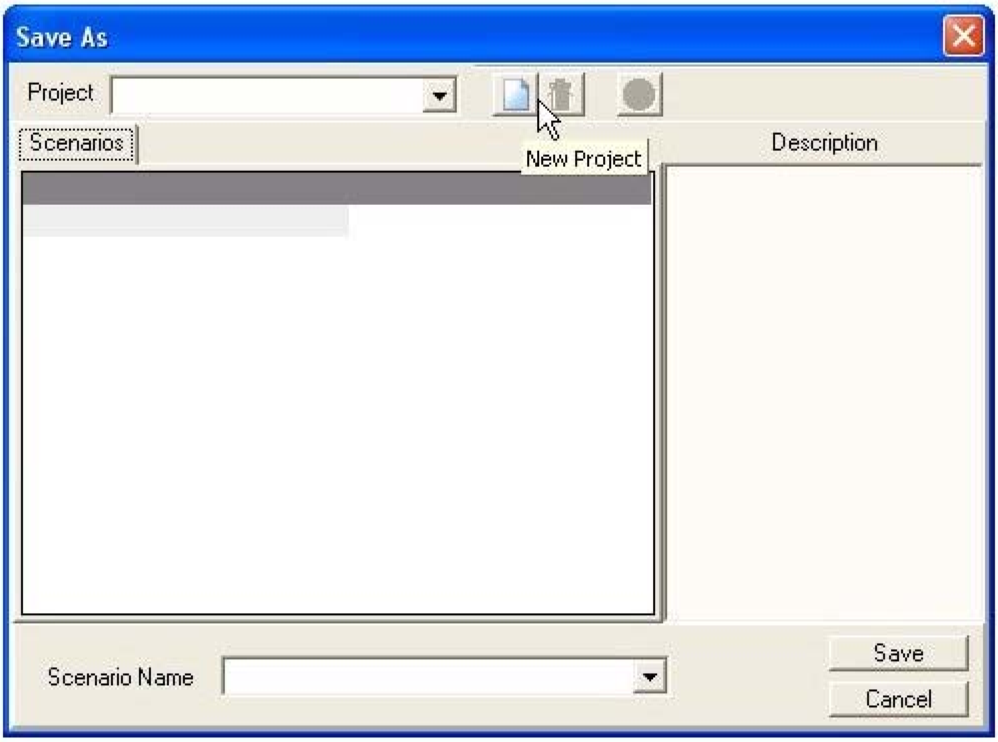
By selecting **Window** from the main menu of the Main Form, the user can go back to the list of scenarios in memory and restore the desirable scenario in its prior state. Next to the name of the actual scenario, the symbol √ is displayed.



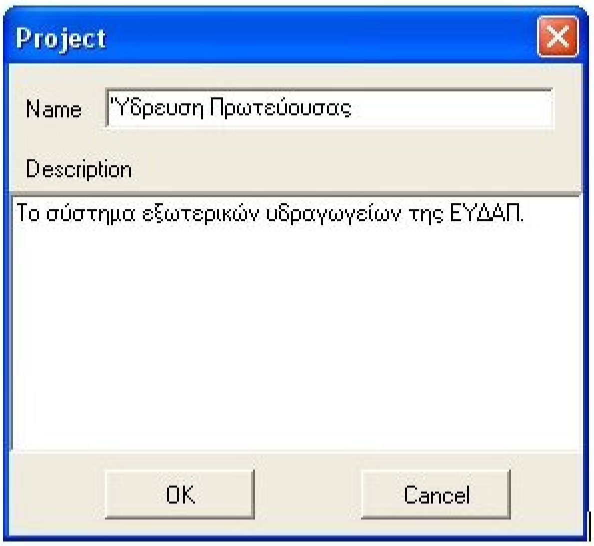
2.3 Creating a new project

A new project is stored in the database through the saving form.

1. From HYDRONOMEAS main menu, select **File/Open** or click on the respective icon.
2. In the dialog box displayed, click on the **New project** icon.



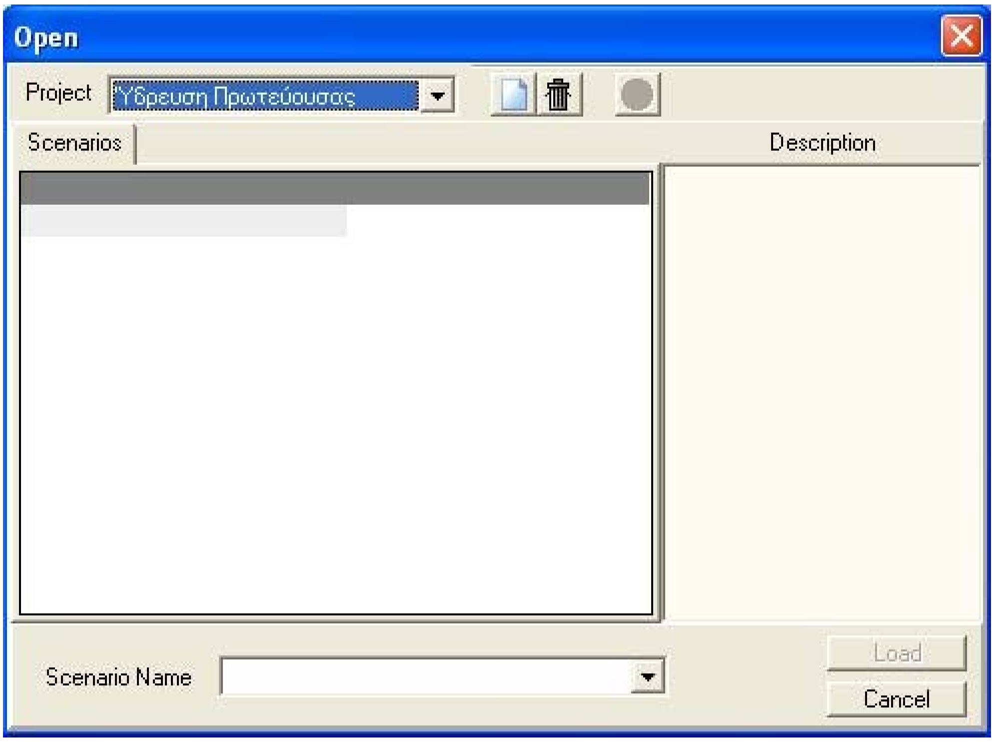
3. In the project input form displayed, the **Name** field shows the name of the project.
4. In the **Description** area, a short description of the project may be provided.
5. Confirm the creation and saving of the new project in the database, clicking **OK**. Conversely, clicking on **Cancel**, the dialog box closes without creating the project.



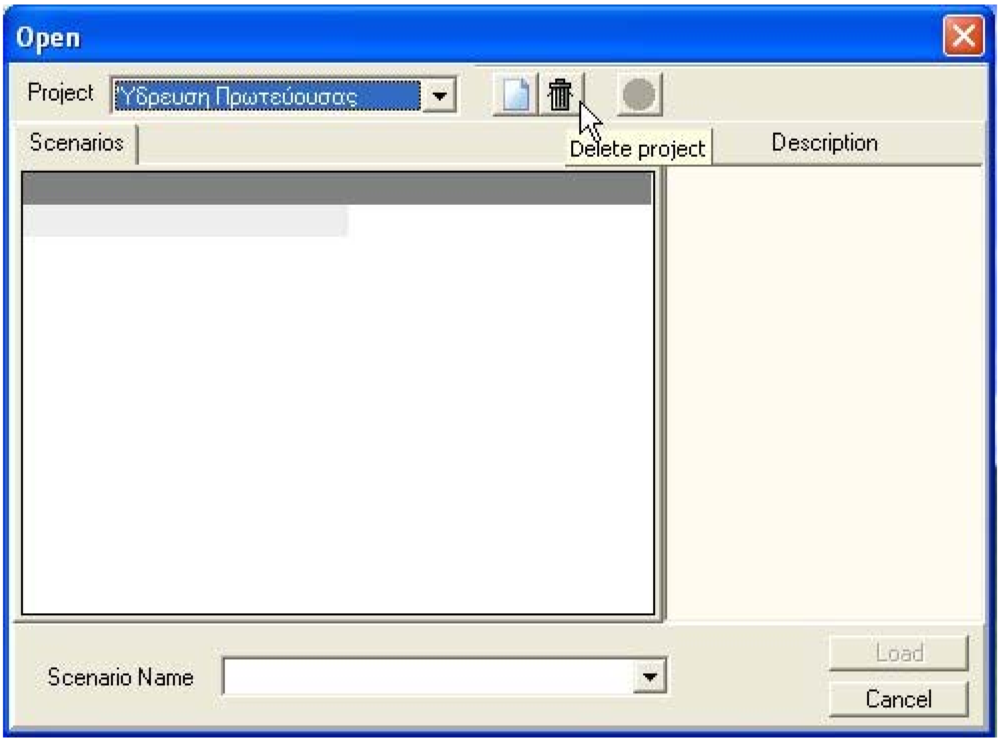
2.4 Deleting a project

A project and all scenarios belonging to this project can be deleted from the database either from the open form or the saving form.

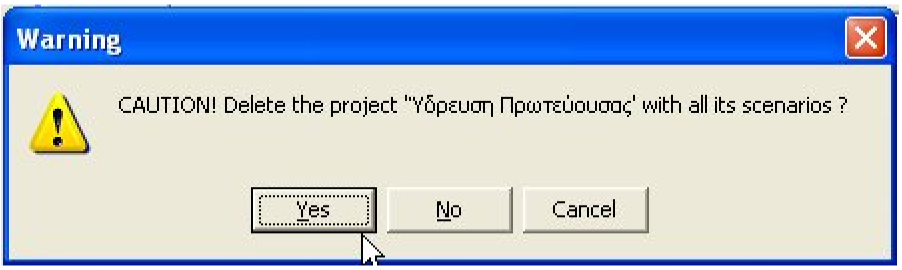
1. From HYDRONOMEAS main menu, select **File/Open** or click on the respective icon.
2. Select a project from the **Project** menu.



3. Click on the **Delete project** icon..



4. In the following dialog box, confirm the deletion of the project from the database.

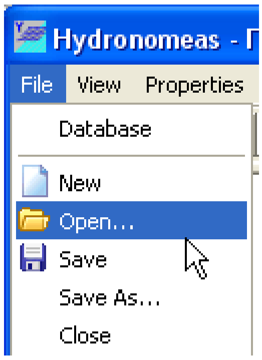


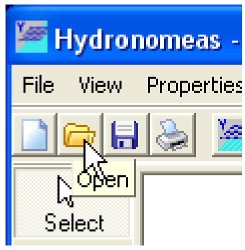
Attention: The deletion of a project from the database is irreversible. This process also deletes all project's scenarios and all data belonging to these scenarios.

2.5 Reading a scenario

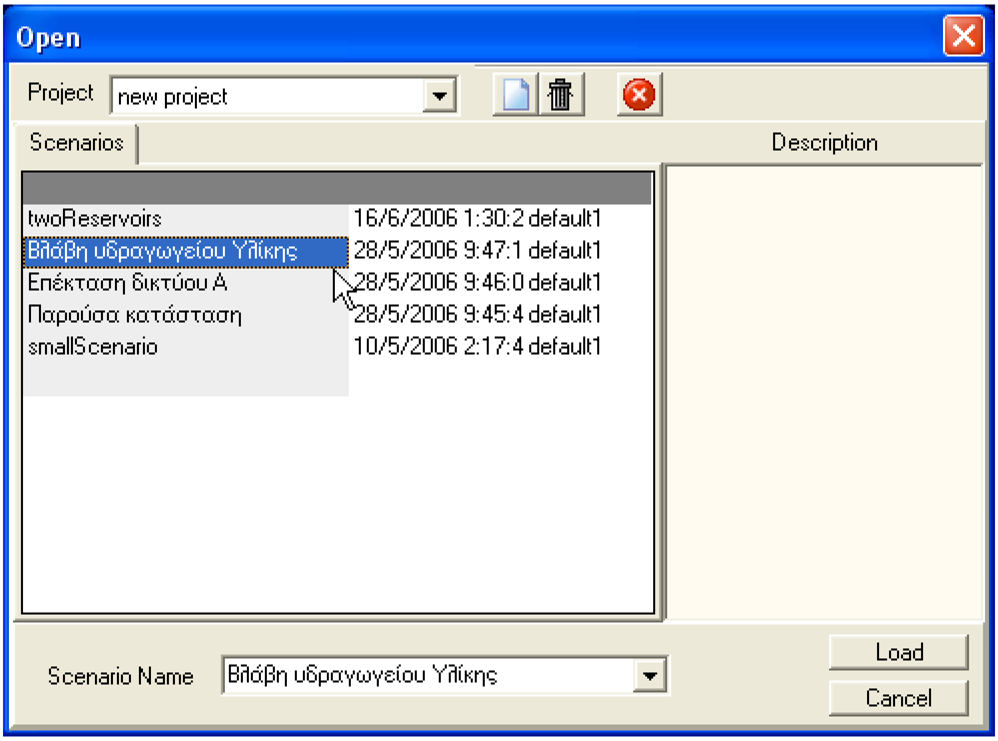
Scenarios that are stored in the database can be imported as follows:

1. From the main menu, select **File/Open** or click on the **Open** icon.





2. Select a scenario from the dialog form.



3. Click the Load button.

2.6 Saving a scenario

By saving, all scenario data are entered in the database from where they can subsequently be recovered.

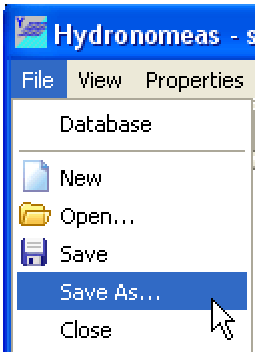
Saving changes to scenarios

Changes made to loaded scenarios can be saved by by selecting **File**/**Save** from the menu of the Main Form or by clicking the **Save** icon. If the scenario has not been saved in the database yet, the scenario saving form is opened (see renaming a scenario).

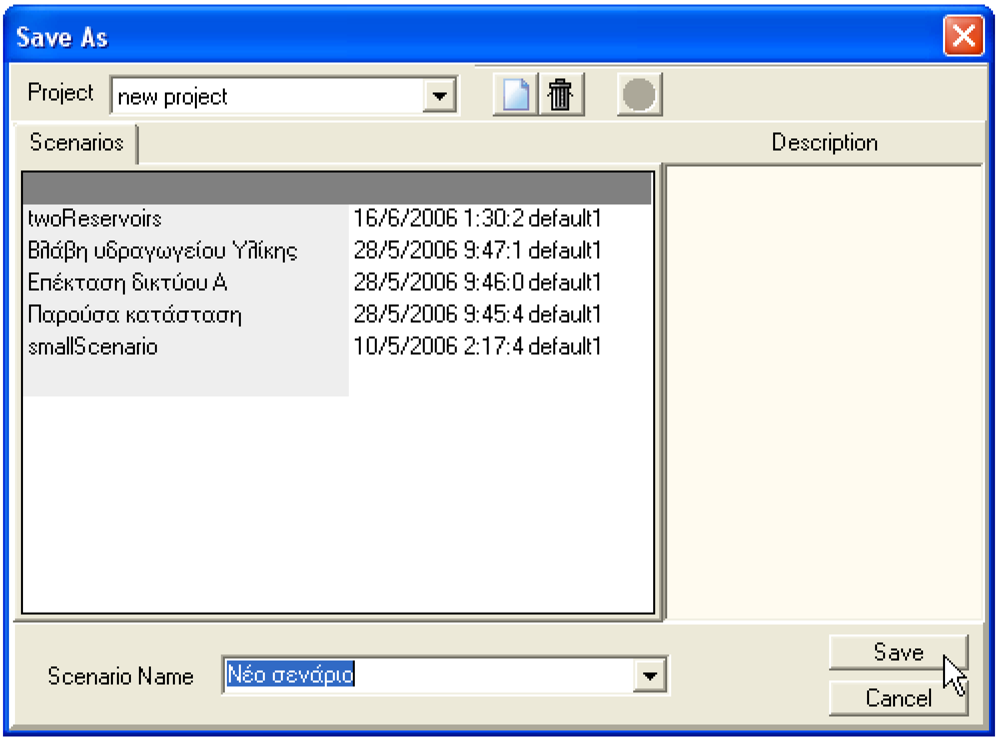
Renaming a scenario

In case where the scenario has not received yet its final name, i.e. it has not yet been entered in the database, or the user chooses to save the scenario with a new name, the following procedure must be followed:

1. From the main menu, select **File/Save as**.

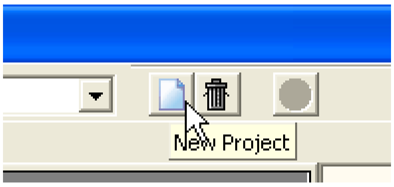


2. In the saving form displayed, the **Scenario Name** field shows the name of the scenario. In the **Description** area, a short description of the scenario can be entered.



3. Complete the process, clicking the **Save** button.

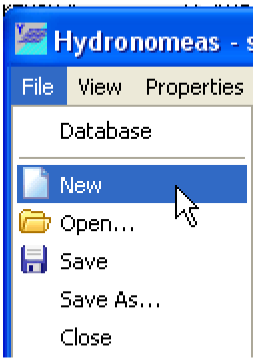
Note:In case where no project exists in the database, a new project should first be created by selecting the **New Project** icon.



2.7 Creating a scenario

The user can create a new, empty scenario in the following ways:

- By selecting **File/New** from the Main Form menu



- By selecting the **New** icon from the basic operations icons of the Main Form

The desktop is automatically cleared and the new scenario is assigned a **temporary name** (e.g. New Scenario 1) which is shown in the header of the main form. A **final name** is assigned to the new scenario upon saving it.

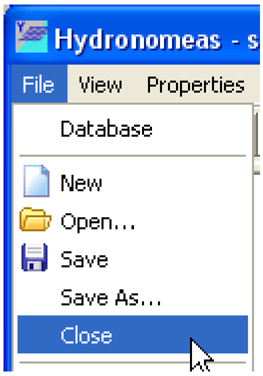
Note that, together with the new scenario, all other scenarios that may have been loaded in the database are kept in memory. Any of these scenarios can be restored in the foreground (see Actual scenario)

Moreover, the new scenario and all changes made to it are saved in the database only upon the relevant action by the user (see saving a scenario).

2.8 Closing a scenario

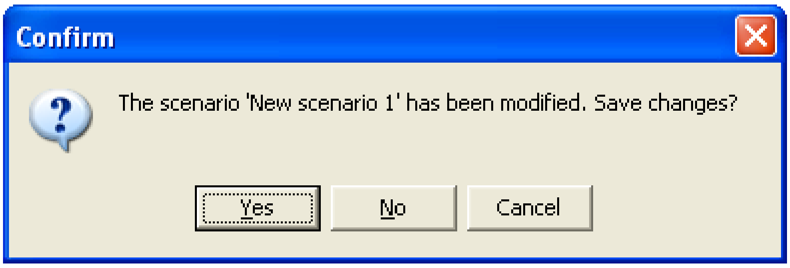
From the scenarios stored in HYDRONOMEAS memory, the user can close the actual scenario (the one displayed on user's screen) by following one of the procedures below:

- Clicking the **X** symbol on the top right corner of the main form
- by selecting **File/Exit** from the options menu.



Moreover, when exiting HYDRONOMEAS by selecting **File/Exit** from the options menu, all scenarios loaded in memory will close.

In case where the user attempts to close a scenario that has not been saved, the following dialog box appears:



From this, the user is prompted to select one of the following procedures:

Yes: The scenario is first saved and then closed. In case where it has not yet been assigned a final name, the scenario saving dialog form is displayed.

No: The scenario closes without having been saved and all changes made since the last saving are lost.

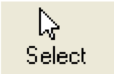
Cancel: The procedure is canceled: The scenario is not closed and saved and the user resumes the control of the system.

Part III

3 Development of a Hydrosystem Model

3.1 Network Design

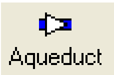
The first step in designing a model usually is to design the network and define its characteristics. On the left part of HYDRONOMEAS Main Form's desktop, you can see the network design tools:



Select: Select a network component

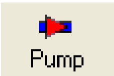
Delete: Delete a network component

River: Insert a river segment

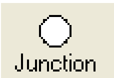


Aqueduct: Insert an aqueduct

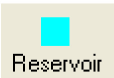
Turbine: Insert a turbine



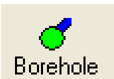
Pump: Insert a pump



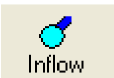
Junction: Insert a junction



Reservoir: Insert a reservoir



Borehole: Insert a borehole/borehole groups



Inflow: Insert a network inflow

Target: Insert a target

Using the above tools, clicking on the relevant button and then on the network design area, the user can:

- insert new network components
- delete the existing components
- modify the properties of network components

The network components are distinguished into autonomous, i.e. those which may exist regardless of the presence of others and dependent, i.e. those that must specifically be related to one or more components.

Autonomous components are

- the aqueduct junction
- the river junction
- the reservoir.

The **dependant components**, when inserted, must be connected to the network as follows:

Dependent component	Connection component
Aqueduct	junction, reservoir (upstream and downstream)
River	river junction, reservoir (upstream and downstream)
Pump	junction, reservoir (upstream and downstream)
Turbine	junction, reservoir (upstream and downstream)
Borehole	junction, reservoir
Inflow	river junction, reservoir
Target	junction, reservoir, aqueduct, river, turbine

3.1.1 Inserting a network component

To insert an autonomous component

1. Select the relevant button from the design tools of the Main Form and then
2. Click the component to place it on an empty place of the network design area

To insert a dependent component

1. Select the relevant button from the design tools of the Main Form and then
2. Select the connection component on the drawing. In the case of lines, in particular (aqueducts, rivers, turbines, pumps), you must also select a second connection component. In the case of aqueducts and rivers, if you select, in the place of a connection component, an empty part of the network design area, a junction is automatically created on this part, with which the dependant component is connected.

Clicking once on one of the Aqueduct or River buttons, the button is held down permitting the user to enter multiple lines in the form of polylines. Conversely, after entering other network components, the Select button is again activated.

Insertion of network components is initially made without having set their properties or with some temporary values for some of them (e.g. name). The user can subsequently insert or modify, before performing calculations, their characteristics (see modifying the network component properties). The insertion of targets forms an exception. After selecting with the mouse the connection component, the target data input form is displayed.

3.1.2 Deleting a network component

A network component can be deleted as follows:

1. By clicking the **Delete** button from the network design tools.
2. By selecting the relevant component from the network design area
3. By confirming the deletion from the dialog form (**Yes**)

Notes:

The dialog form for confirming the component deletion is displayed only if the relevant option is active (see Confirming a deletion).

Where other network components depend on the component to be deleted, then the component will not be deleted and a relevant message will appear. Exceptionally, when the recursive deletion option is active, the selected component and all its dependant network components are simultaneously deleted.

3.1.3 Modifying the network component properties

To modify the details of a network component, use the component data form, which can be displayed on the screen in one of the following ways:

1. Double-clicking on any component from the network design area (junction, aqueduct, borehole, etc.)
2. From the network component tables that are displayed by selecting **Properties** from the menu of the Main Form and then the category of the component

From the component data form, the user can modify the component's characteristics and record the changes by clicking **OK** at the lower part of the form. Conversely, by clicking **Cancel** all changes are cancelled.

3.1.4 Junction

The Junction is the principal aqueduct network component, since it determines the start and the end of an aqueduct or constitutes a connecting point of other components of the network. In the network's model, no distinction is made between the different junction types, since all junctions are dealt with in the same way. Thus, a junction in HYDRONOMEAS can, for example, actually represent:

- a connecting point of a borehole on the network

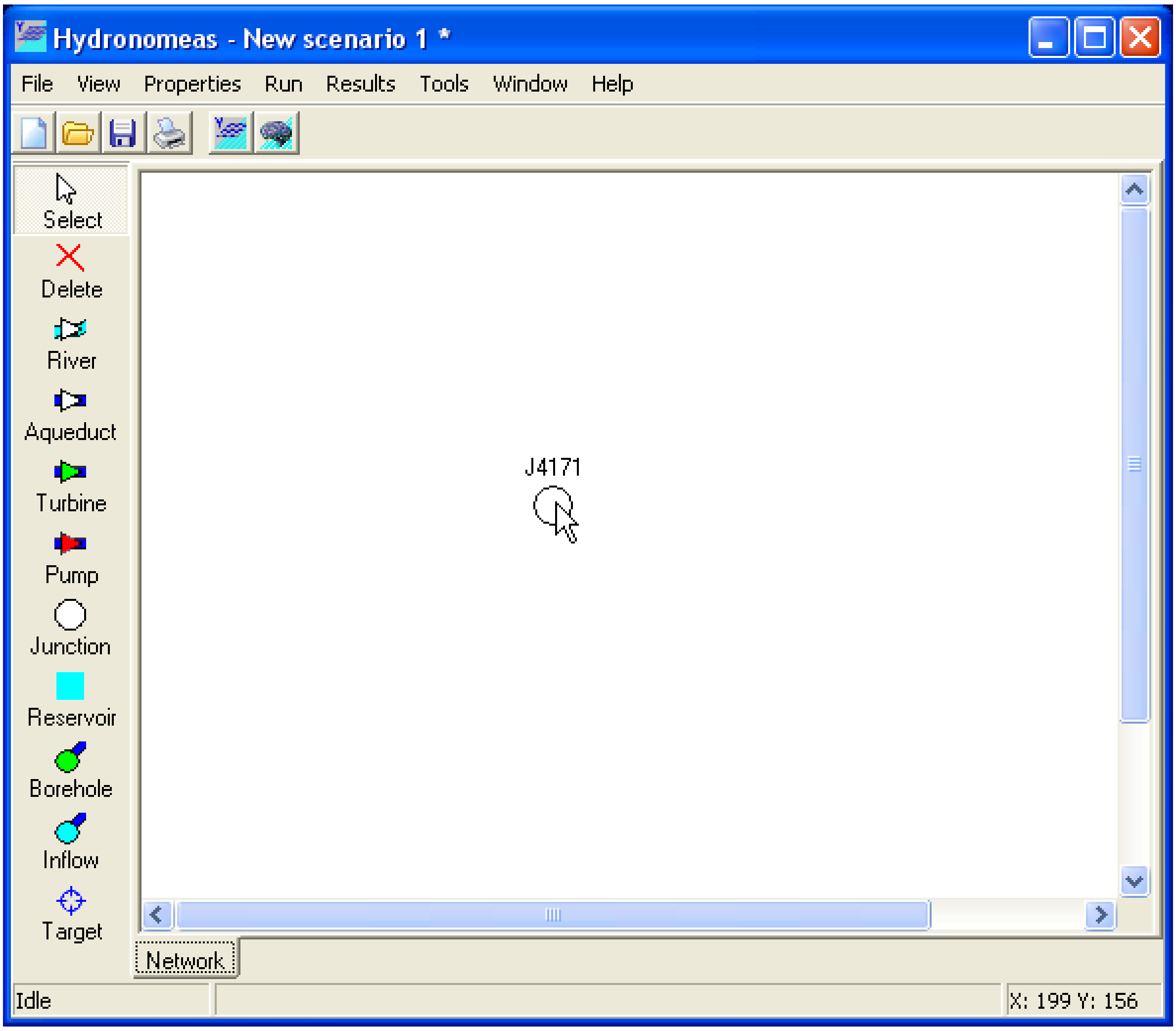
- a bifurcation
- a water treatment plant
- a demand area for supply or irrigation water
- an outflow from the hydrosystem

A junction can also be created for simulation reasons, e.g. to connect two parts of the same aqueduct which however have different characteristics.

Inserting a new junction

A junction is created as follows:

1. By clicking the **Junction** button from the network design tools
2. By then clicking on an empty part of the network design area.

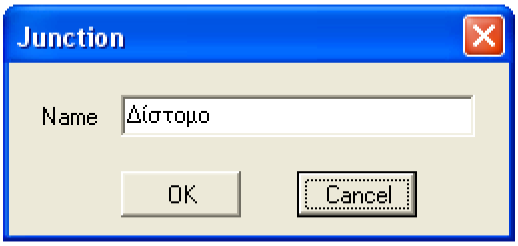


Note: A network junction can be automatically created when inserting an aqueduct as an upstream or downstream junction.

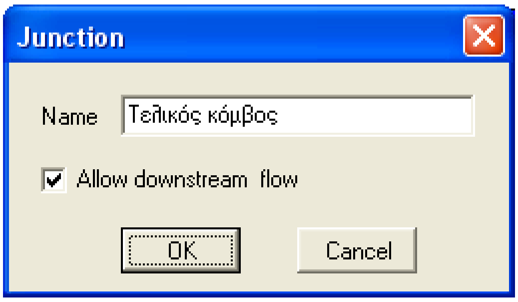
Modifying a junction's data

The properties of a junction can be modified as follows:

1. On the network design form, double-click on the junction
2. On the displayed junction data form, you can modify the **Name**.



Only in the case of a final junction, the **Allow downstream flow** option is displayed, with which the user can permit upon simulation the water outflow from the system through this junction.



3. Click the **OK** button to record the changes

Notes:

The junction data form can be also displayed from the aggregate junction list (see network component list).

The aqueduct junction is displayed on the network's diagram as a white circle and it has different color that the river junction (blue circle).

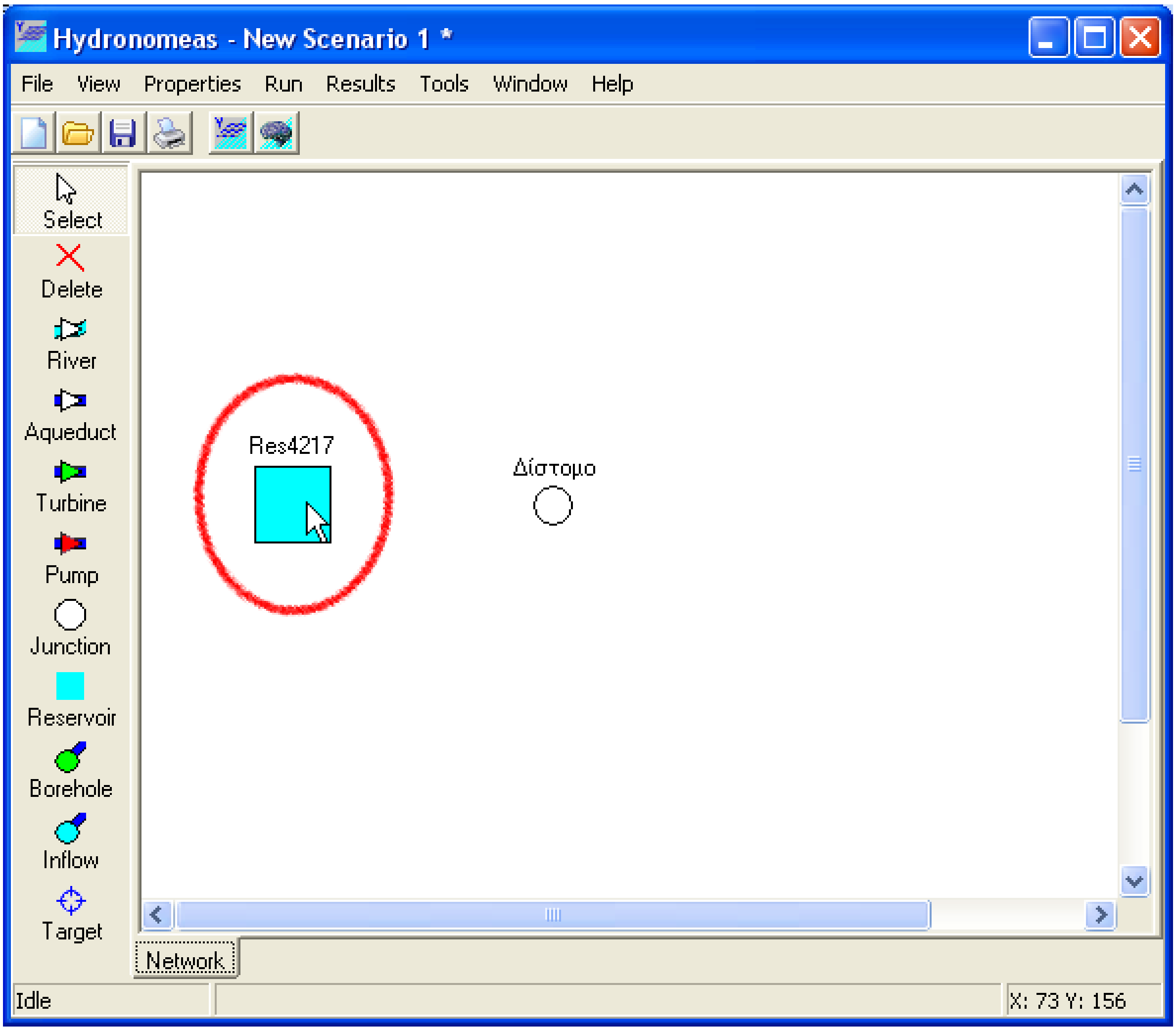
3.1.5 Reservoir

Inserting a new reservoir

A reservoir is created as follows:

1. By clicking the **Reservoir** button from the network design tools

2. By then clicking on an empty part of the network design area.



3. The reservoir's symbol is displayed on the design area with a temporary name

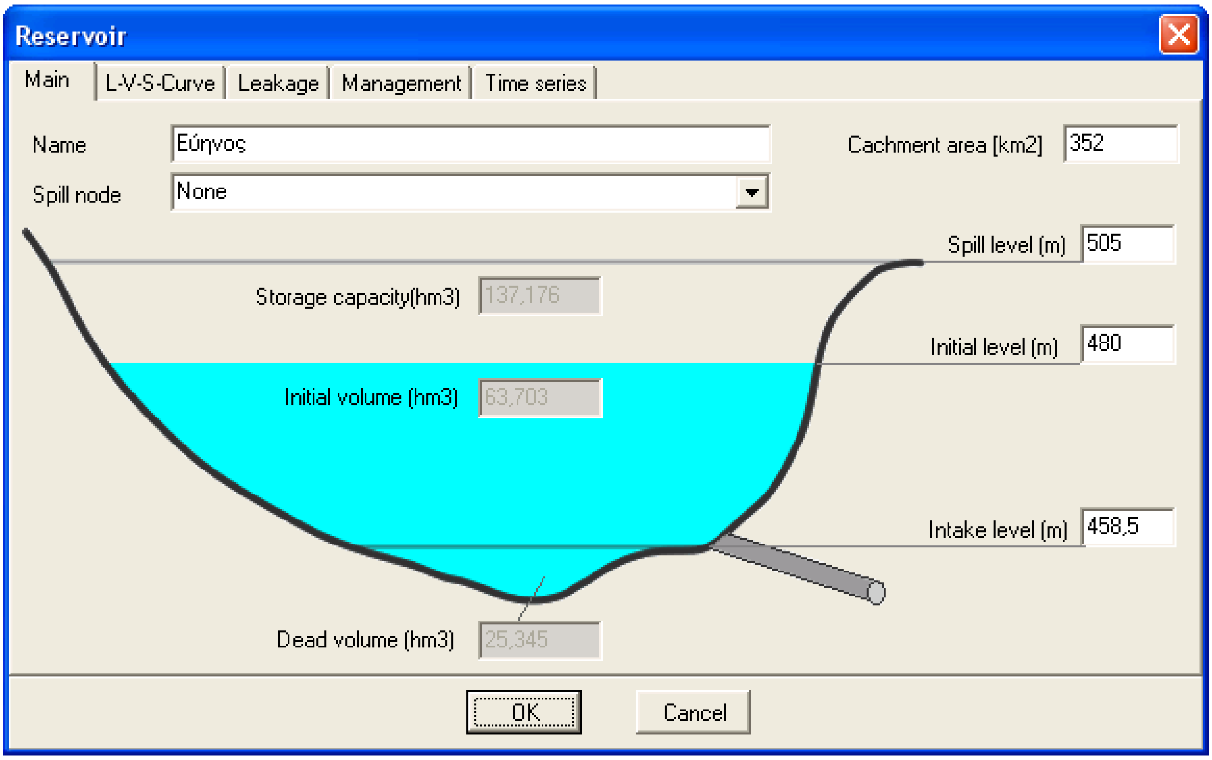
Modifying a reservoir's data

A reservoir's properties can be modified from the reservoir data form displayed by double-clicking on the reservoir's icon in the network design form.

The reservoir data form is comprised of the following sheets

- The main data sheet
- The level – volume – area curves sheet
- The leakage data sheet
- The management rules data sheet
- The time series sheet

Basic data

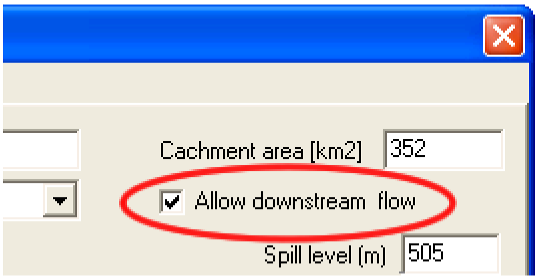


From the main sheet, the following reservoir data can be modified

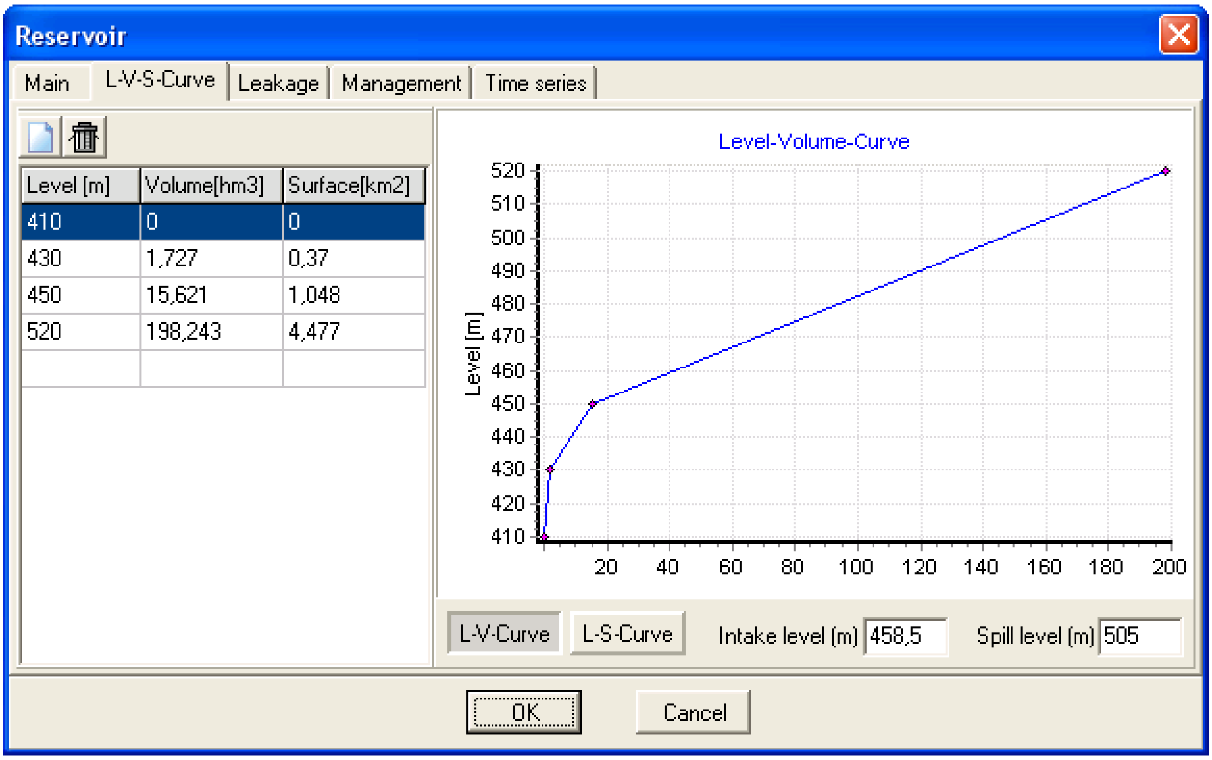
1. The **Name**.
2. The catchment area of the reservoir in km^2 **(Catchment area)**.
3. The river node where the reservoir's spill goes **(Spill node)**. The node is selected from the drop-down menu that includes all the river nodes. In case where spills escape from the system and therefore they are not taken into account downstream in the model, then select **None** in the menu.
4. The **Spill level** in m that corresponds to the reservoir's **Storage capacity**.
5. The **Initial level** in m that corresponds to the reservoir's **Initial volume** at the beginning of the simulation.
6. The **Intake level** in m that corresponds to the reservoir's **Dead volume**.

Note:To display the reservoir's capacity, initial volume and dead volume values, you must previously set the level-volume curve.

In case where the reservoir is the final junction of the system, i.e. there is no aqueduct or river downstream of the reservoir, then on the right top part of the sheet the **Allow downstream flow** option is displayed, with which the user can permit upon simulation the runoff of excess water from the system through the reservoir (regardless or any spills).

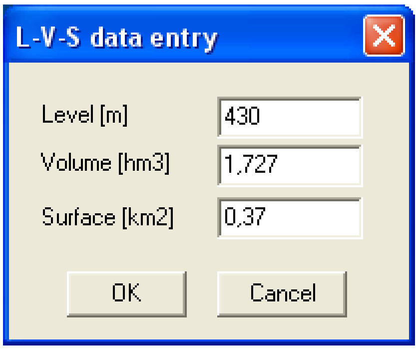


Level-volume-area curves



From the level-volume-area data sheet, the user can set the characteristic points of the curve. The left part of the sheet shows the point table, and the right part shows the graph of the level-volume-area curve. To enter data:

1. Click on the **new record** icon or double-click on the last (empty) line of the table.
2. In the point data form, enter the values of **Level** in m, **Volume** in hm^3 and **Surface** in km^2.



3. Confirm the record by clicking **OK**.

You can delete a curve's point as follows:

1. Select the relevant line from the table.
2. Then click the **delete selected record** icon.

You can modify the values of the table as follows:

1. Double-click on the line to be modified.
2. Make the desirable charges in the point data form that appears.
3. Confirm the changes by clicking **OK**.

Notes:

- Before performing the simulation, you need to determine at least three curve points for each reservoir.
- Intermediate values are estimated upon simulation by a logarithmic interpolation.

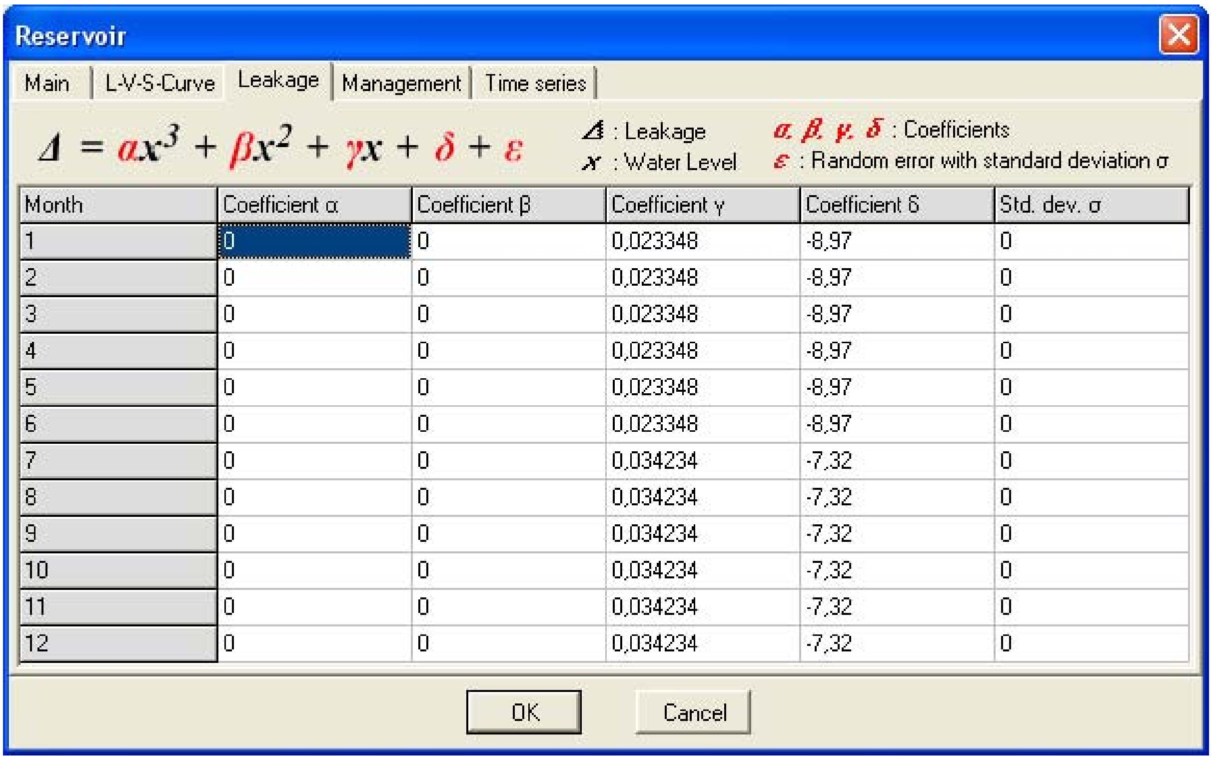
The curve's data are displayed in the table always classified as to the level. By clicking the **L-V-Curve** button, the level-volume graph appears and by clicking the **L-S-Curve** button, the level-surface graph appears. The intake and spill levels, in addition to their respective fields on the main sheet of the form, can also be set from the **Intake level** and **Spill level** fields, at the lower right part of the level-volume-area data sheet.

Leakages

Reservoir leakages are set using parameters from the form's leakage parameter sheet. The equation for calculating the underground runouts is:

$$\Delta = \alpha x^3 + \beta x^2 + \gamma x + \varepsilon + \xi$$

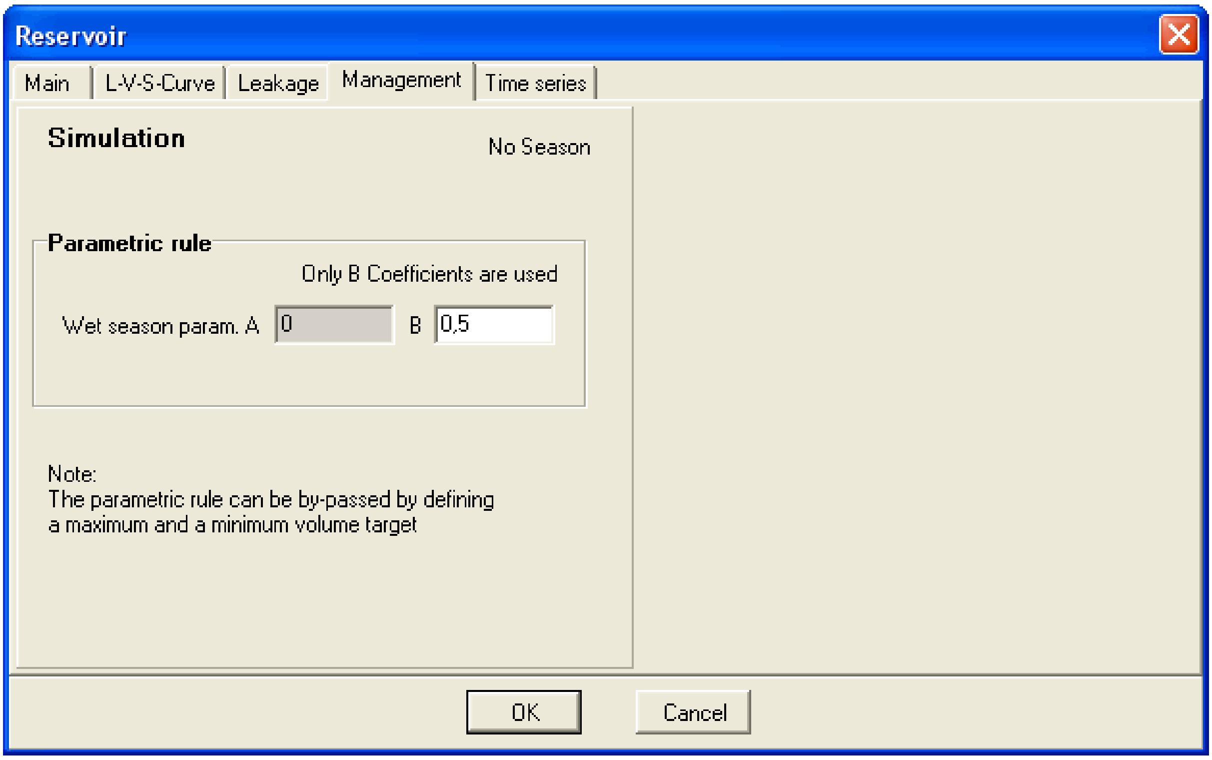
Where **Δ** are the leakages in hm3, **x** the reservoir's level in m, **α, β, γ** and **ε** the equation's coefficients and **ξ** a random error condition that is considered to follow a normal distribution, zero mean value and standard deviation **σ** (in hm3). The user can set separate values for each month of the year, for all the equation's parameters and for the standard deviation.



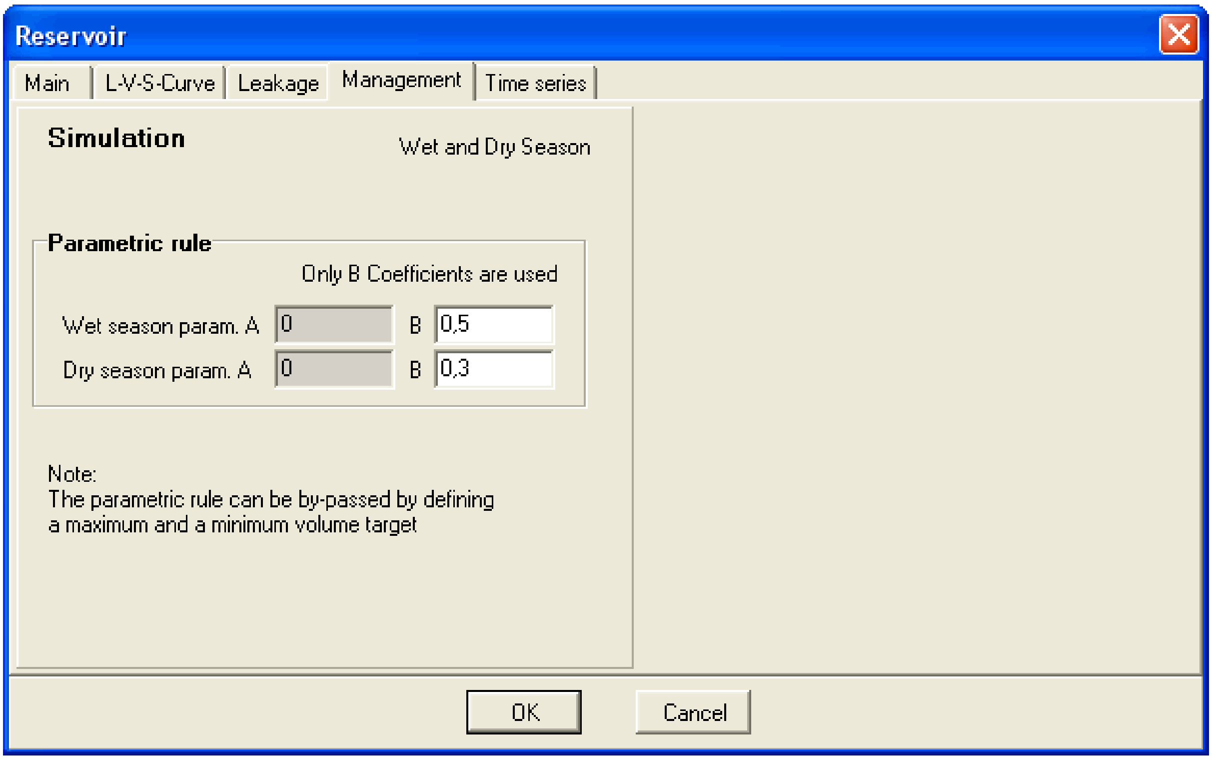
Month	Coefficient α	Coefficient β	Coefficient γ	Coefficient δ	Std. dev. σ
1	0	0	0,023348	-8,97	0
2	0	0	0,023348	-8,97	0
3	0	0	0,023348	-8,97	0
4	0	0	0,023348	-8,97	0
5	0	0	0,023348	-8,97	0
6	0	0	0,023348	-8,97	0
7	0	0	0,034234	-7,32	0
8	0	0	0,034234	-7,32	0
9	0	0	0,034234	-7,32	0
10	0	0	0,034234	-7,32	0
11	0	0	0,034234	-7,32	0
12	0	0	0,034234	-7,32	0

Operation rule

In the 4th sheet of the reservoir data sheet, HYDRONOMEAS provides to the user the possibility to control the reservoir's operation through a simple and effective parametric rule. The rules can be seasonally modified (see options form), and the sheet has one of the following forms, depending on this option:



Form of operation rules sheet without seasonal differentiation



Form of operation rules sheet with seasonal differentiation

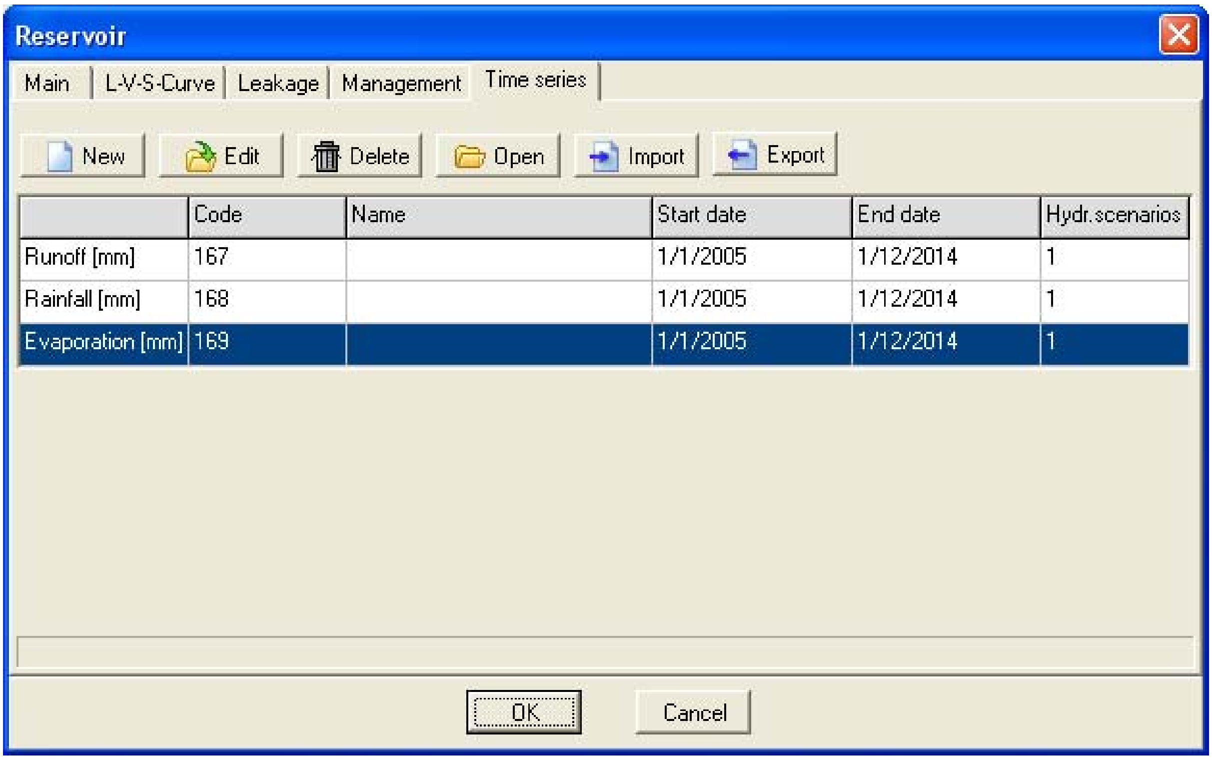
The **Parametric rule** area includes four fields where the user enters the parameters α and β for the wet season **(Wet season param.)** and the dry season **(Dry season**

param.). In the latter case, the fields are displayed only if seasonal modification has been selected. Moreover, in case where parameter α is deactivated, the parameter's respective fields have grey background.

If the **Target volume rule** has been selected, the **Target volume wet season** and **Target volume dry season** are active, if seasonal differentiation is selected. The values entered are expressed in cubic meters (hm3).

More information on this issue: Reservoir Operating Rules and Nalbantis and Koutsoyiannis, 1997.

Time series



On the last sheet of the form, the user is prompted to set three time series for each reservoir:

1. time series of runoff in the reservoir.
2. time series of rainfall on reservoir's surface.
3. time series of evaporation.

All values are shown in mm and for each time series set, the following information is provided:

1. time series **Code**.
2. time series **Name**.
3. time series **Start date**.
4. time series **End date**.
5. number of **hydrological scenarios** contained in the time series.

For the management of time series data, the following actions are available through the relevant buttons of the time series sheet:

- Create a new time series **(New...)**. From the form displayed, it is possible to create a new time series with multiple modules (see Editing Time Series Data).
- Edit a times series **(Edit...)**. From the form displayed, it is possible to edit a time series (see Editing Time Series Data).
- Delete a time series **(Delete)**.
- Open from the database **(Open...)**. A relevant form is displayed through which, the user can search and select a time series from the database (see Importing time series from the database).
- Import from file **(Import...)**. A dialog form appears for selecting and importing a time series file.
- Export in file **(Export...)**. A dialog form appears for exporting a time series in a file.

Notes:

- Saving a time series in the database is made when saving the entire scenario.
- In case where no reservoir time series has been set, the user is prompted for this before performing the simulation, which however shall be ordinarily performed, without considering the relevant input or output of the reservoir.
- More information: Hydrological Scenarios and Time Series

3.1.6 Aqueduct

The term aqueduct refers to a structure of finite capacity that connects two junctions of the hydrosystem. An aqueduct can represent a single conduit or a system of conduits in line, for example:

- pipelines
- channels
- tunnels
- siphons

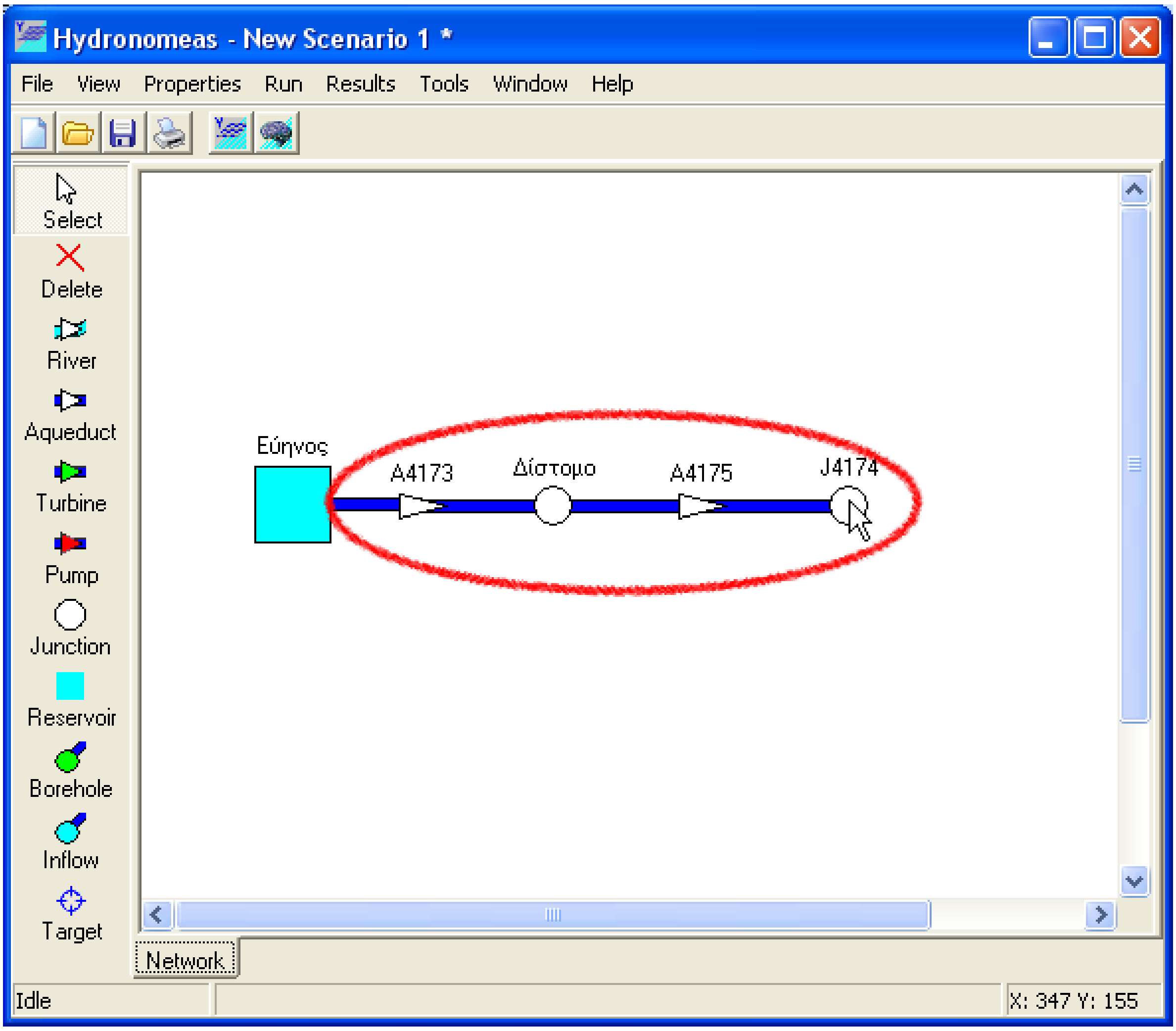
Inserting a new aqueduct

An aqueduct as a dependant component of a network is defined by the network's upstream and downstream components, which can include the following:

- Junction
- River node
- Reservoir

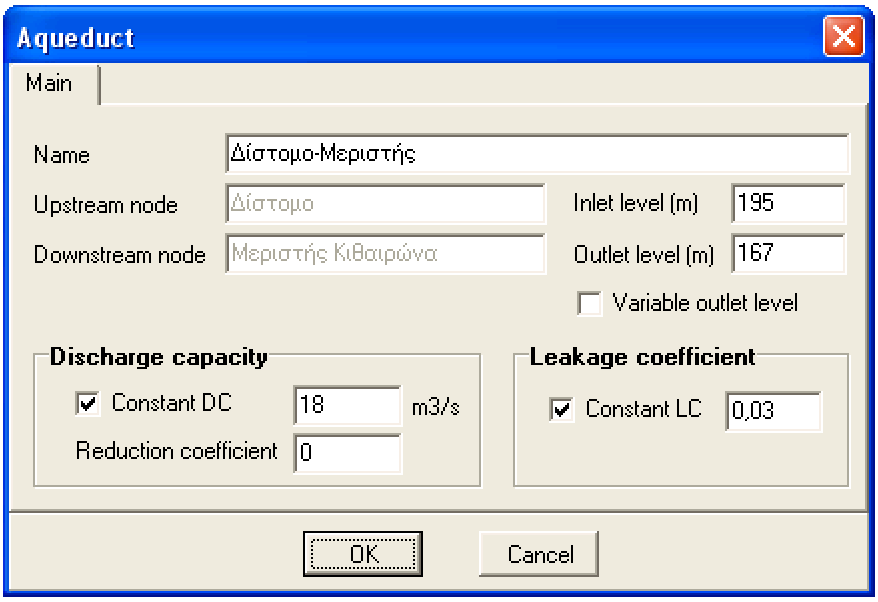
An aqueduct is created as follows:

1. Click the **Aqueduct** button from the network design tools
2. Then consecutively click on two of the above components on the network's design area. If you select, in the place of a connection component, an empty part of the network design area, a junction is automatically created on this part, with which the aqueduct is connected.
3. If you continue to click on the network design area, additional conduits are consecutively created in the form of polylines.



Modifying an aqueduct's data

Insertion of an aqueduct is initially made without having set its properties or with some temporary values for some of them (e.g. name). The properties can be modified by double-clicking on the aqueduct in the network design area.



The aqueduct data form lists the following properties:

- The **Name** of the aqueduct.
- The **Upstream node** and **Downstream node** that define the aqueduct. These fields appear inactive.
- The **Inlet** and **Outlet levels** of the aqueduct in m.
- The **Variable outlet level**, which applies only in case where the downstream node is a reservoir, where it is true if the outlet level of the conduit is the same with the level of such reservoir.
- The leakage coefficient area.
- The discharge capacity area.

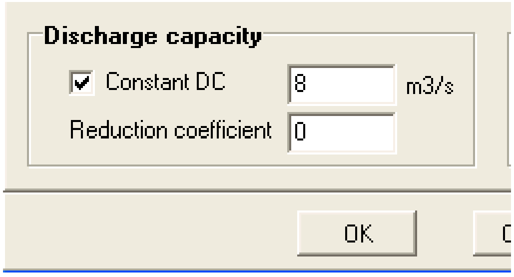
3.1.6.1 Discharge capacity of aqueduct

An aqueduct, regardless of its type (gravity, with pump, with turbine) has a maximum limit of water discharge, i.e. a **discharge capacity**. The discharge capacity can:

- remain constant.
- vary in conjunction with the head, i.e. the difference of the level of water upstream and downstream the aqueduct.
- vary in conjunction with time.
- vary in conjunction with head and time.

Constant discharge capacity

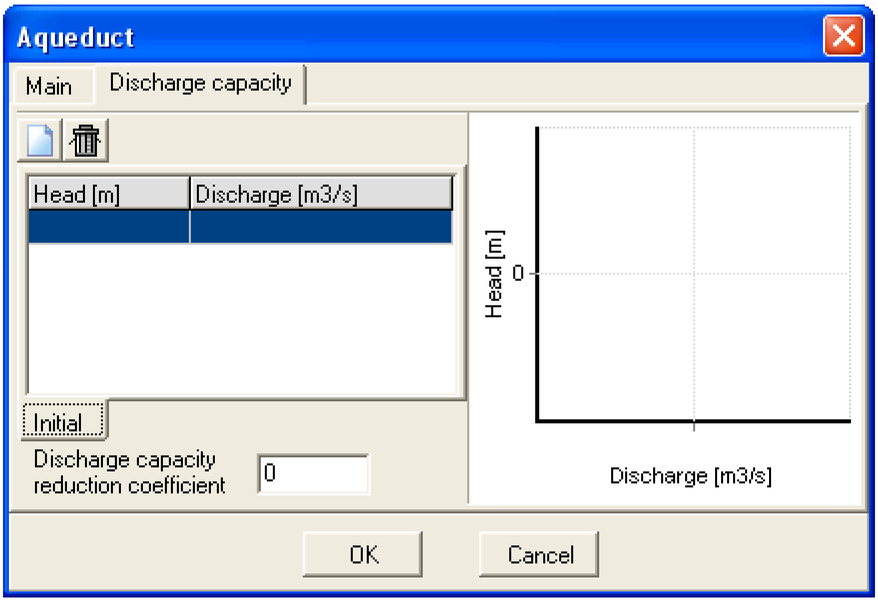
The constant discharge capacity is set in the network component's data sheet (aqueduct, pump, turbine) having selected the **Constant DC** option from one and single record in the discharge capacity field. The value is shown in m^3/s, remains constant throughout the simulation and is not influenced from any variations of the head.



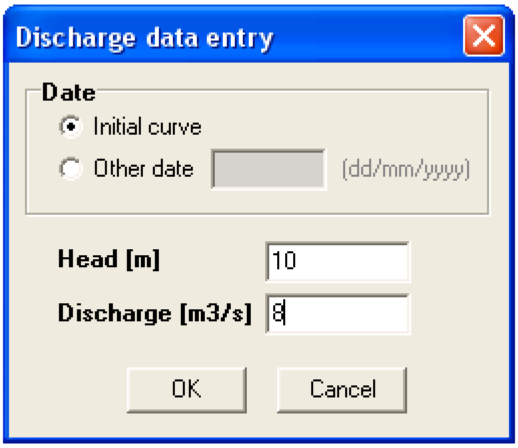
Variable discharge capacity in conjunction with head

In case of closed aqueducts, the discharge capacity can vary in conjunction with the head, which depends on the current level of reservoirs upstream and downstream the aqueduct (only if **Variable outlet level** option is true). Variable discharge capacity in conjunction with head is set as follows:

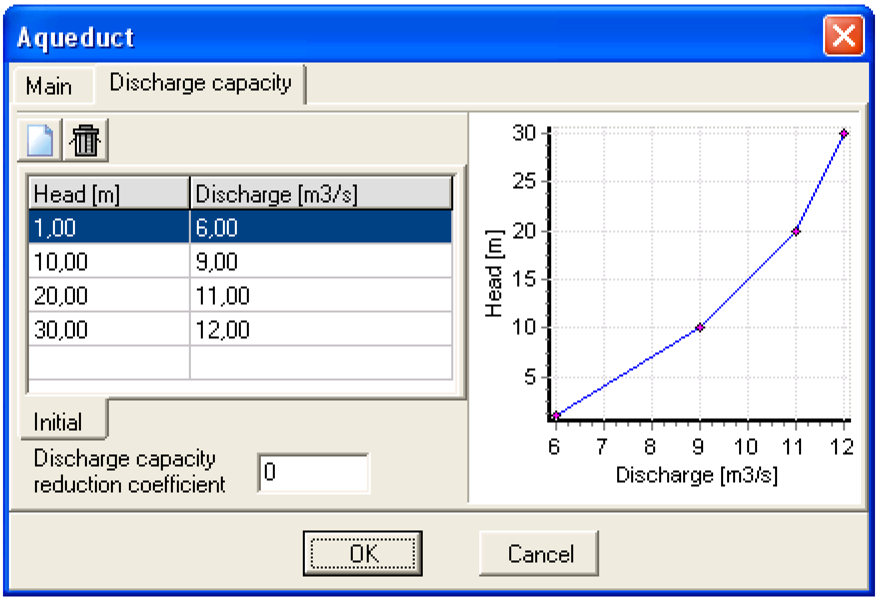
1. Disable the **Constant DC** option from the main sheet of the form.
2. Select the **Discharge capacity** sheet.



3. Click on the **new record** icon or double-click on the last (empty) line of the table.
4. Enter the **Head** field in σε m and **Discharge** field in m^3/s.



5. Confirm the values by clicking **OK**.
6. Repeat the last steps until the head-discharge capacity curve is configured. The table lists the records classified as to the head. The right part of the sheet shows the curve's graph. .



Note: You cannot record two different discharge capacity values for the same head.

To delete a record:

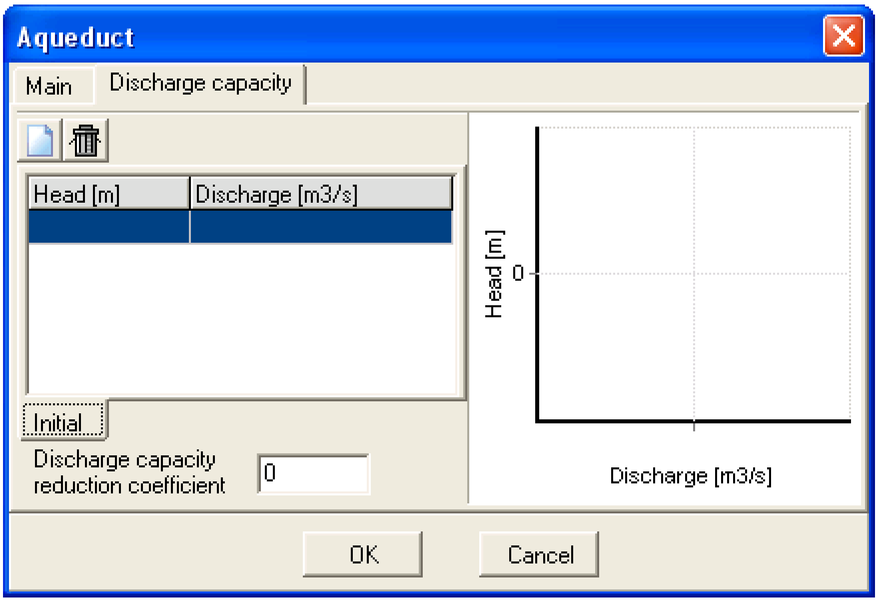
1. select the line in the discharge capacity table.
2. click the **Delete** icon.

Variable discharge capacity in conjunction with time

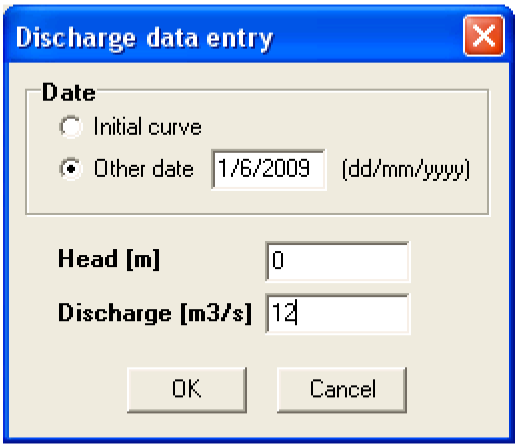
The aqueduct discharge capacity does not need to remain constant throughout the simulation. HYDRONOMEAS offers to the user the possibility to change the value of discharge capacity in order to respond to planned changes (e.g. temporary shutdown for network maintenance reasons, increase of discharge capacity due to development works).

Variable discharge capacity in conjunction with time is set as follows:

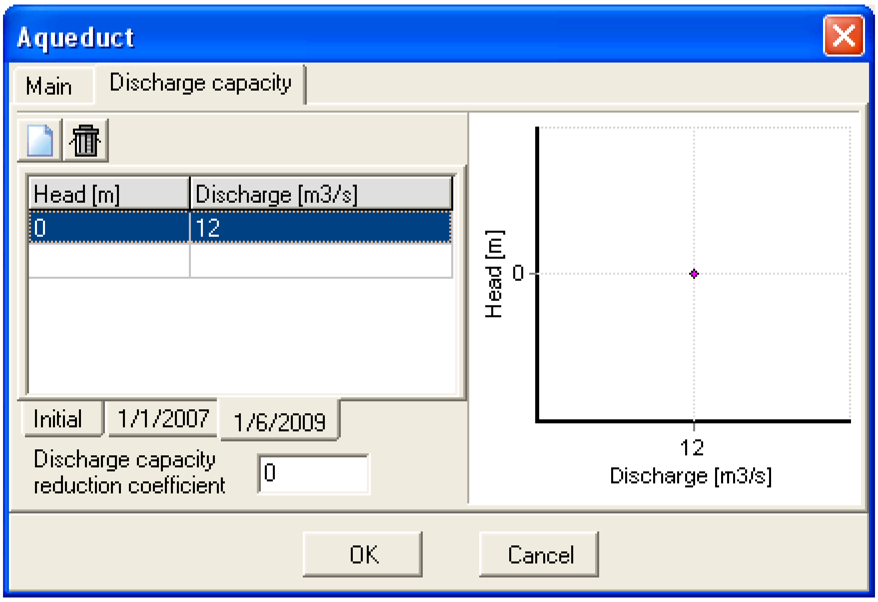
1. Disable the **Constant DC** option from the main sheet of the form.
2. Select the **Discharge capacity** sheet.



3. Click on the **new record** icon or double-click on the last (empty) line of the table.
4. Select input of data that will apply from the beginning of the simulation **(Initial curve)** or another date by selecting **other date**.



5. Enter the **Head** field in m and **Discharge** field in m^3/s. In case discharge capacity varies only in terms of time and not in terms of head, then only one value is provided for each date and the value in the Head field is not taken into consideration.
6. Confirm the values by clicking **OK**. If data input concerns the beginning of the simulation, then values are entered in the **Initial** sheet. If the values concern a new date, then a sheet for this particular date is created where the values shall be listed. If a sheet exists for this date, then the data shall be listed in this sheet.



7. Repeat the last steps until completing the entry of all discharge capacity data.

To delete a record:

- select the line in the discharge capacity table.
- click the **Delete** icon.

Variable discharge capacity in conjunction with time and head

It is also possible to combine the options of calculating the discharge capacity variable, when the aqueduct discharge capacity is a function of time and head.

Discharge capacity reduction coefficient

The discharge capacity **Reduction coefficient** takes into account time restrictions in the use of the aqueduct and can have values from 0 to 1. The reduction coefficient is defined as follows:

- In the main sheet of the aqueduct data form or
- In the variable discharge capacity sheet in the field.

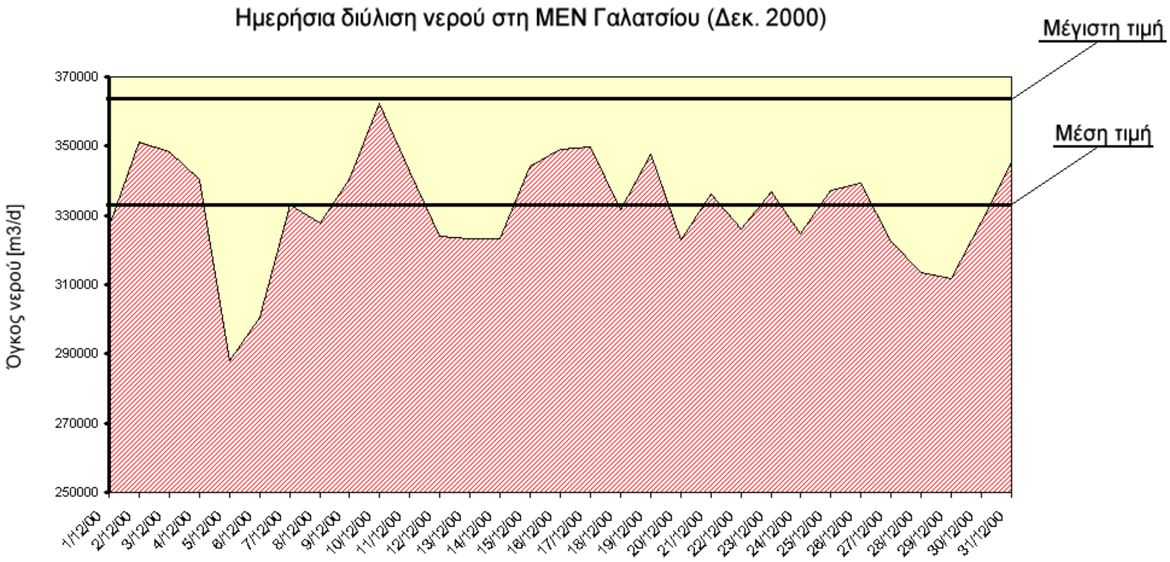
Such coefficient expresses either actual restrictions as to the use of the aqueduct (e. g. a pump operating during specific hours in a day) or virtual restrictions which are imposed to assure a more realistic representation of the hydrosystem's operation, at low time scales. For example, since the model operates on a monthly basis, it cannot take into account the variation of the daily consumption. For this reason, the nominal discharge capacity of aqueducts is reduced by a y coefficient that expresses time restrictions as to the use of the aqueduct and the impact of discharge time variation within the time step, in case where it is not possible to make a material resetting before the consumption junctions. In this case, the values that the coefficient usually takes is the maximum observed deviation between the mean monthly Qavg value and the maximum daily demand Qmax value:

$$y = (Qmax- Qavg)/ Qavg$$

The hydraulic discharge capacity of the aqueduct corresponds to the maximum value and the discharge capacity reduced by the y coefficient corresponds to the mean value.

It is noted that the variation of consumption observed within a 24-hour period is considered to be covered by possibilities of resetting the network's facilities, such as the capacity of aqueducts and the tanks of water treatment units. Otherwise, the y coefficient would have to be incremented in order also to include the variation of consumption observed within a 24-hour period.

The following example provides the water refining readings of Galatsi WTP for December 2000.



Bidirectional flow aqueduct

When there is the possibility of bidirectional operation in a branch of the network (usually with gravity towards one direction and with pumping towards the reverse one), then this is represented using two parallel counter-flow aqueducts. If y_1 is the discharge capacity reduction coefficient of an aqueduct and y_2 of its reverse one, then the following restriction must apply between the two coefficients:

$$y_1 + y_2 <= 1$$

The above restriction ensures that it will not be possible to use both routes at the same time during the time step. Therefore, the total use percentage of the two reverse routes shall not exceed 100% of the available time.

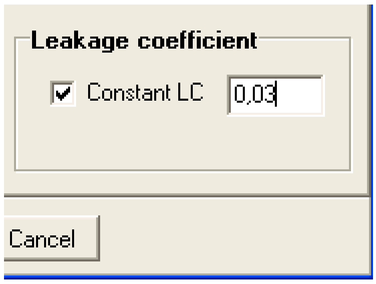
3.1.6.2 Aqueduct leak coefficient

An aqueduct's leak is calculated using a leak coefficient on the aqueduct's discharge. HYDRONOMEAS uses a simplified linear relation between aqueduct discharge and leaks at the simulation time step, which is easier to be estimated following systematic measurements upstream and downstream the aqueduct.

Constant leak coefficient

A constant leak coefficient which shall apply throughout the term of the simulation is defined as follows:

1. In the main sheet of the aqueduct data form, select the **Constant LC** option.
2. The constant leak coefficient field displays a value starting from 0 to 1. If the field remains empty, the coefficient is deemed null..

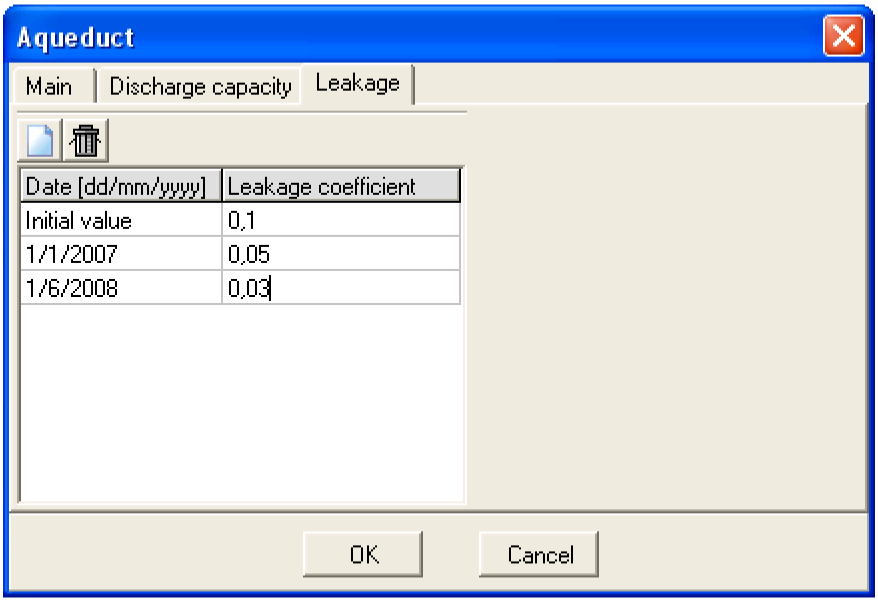


Change of leak coefficient in conjunction with time

HYDRONOMEAS provides the possibility to differentiate the leak coefficient in conjunction with time, in order for the simulation to correspond to different situations, i.e. scheduled aqueduct maintenance works.

Temporally variable leak coefficients are defined as follows:

1. In the main sheet of the aqueduct data form, deactivate the **Constant LC** option.
2. Select the **Leakage** sheet.
3. In the **Initial value** line of the **Leakage coefficient** column, enter the coefficient value (0..1) that will apply at the beginning of the simulation.
4. Clicking the **New** record icon, enter an additional line in the table.
5. In the first column of the new line, enter the date of change of the coefficient value and in the second line, enter the new value if the coefficient that will apply as from this point of time.
6. By repeating steps 4 and 5, enter the new coefficient values in the table fields.



To delete a record:

1. select the line in the coefficient table.
2. click the **Delete** icon.

The first line cannot be deleted; you can only modify the coefficient value.

Null leak

Null leak is considered to exist in all **Pump** aqueducts or **Turbine** aqueducts and when the value field of the leak coefficient in the aqueduct's data form is empty or null, with the constant leak coefficient label selected.

3.1.7 Pump

A pump carries water from one point of the network to another, thus consuming energy. In HYDRONOMEAS, the pump is represented in the model as an aqueduct with additional characteristics used to calculate power consumption.

Inserting a new pump

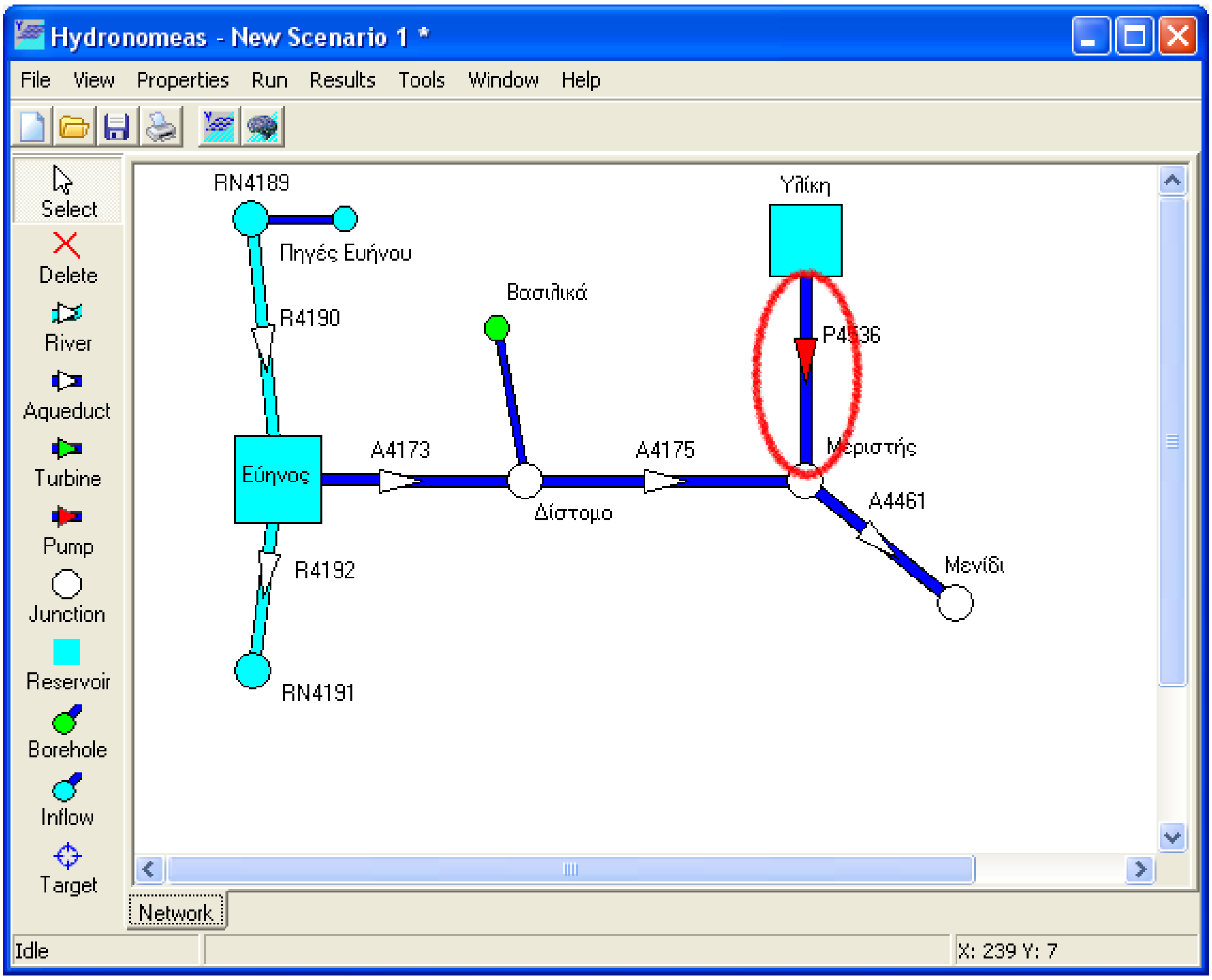
Similarly to an aqueduct, the pump as a dependant component of a network is defined by the network's upstream and downstream components, which can include the following:

- Junction
- River node
- Reservoir

A pump is created as follows:

1. Click the **Pump** button from the network design tools
2. Then consecutively click on two of the above components on the network's

design area.



Modifying a pump's data

Insertion of a pump is initially made without having set its properties or with some temporary values for some of them (e.g. name). The properties can be modified by double-clicking on the pump in the network design area.

The pump data form is similar to the aqueduct data form, with only difference that:

- pumps do not have leaks in the model and thus there is no provision in the form for entering a leak coefficient value and
- energy consumption is defined based on a specific energy coefficient **(y coefficient)** from the **Energy** sheet.

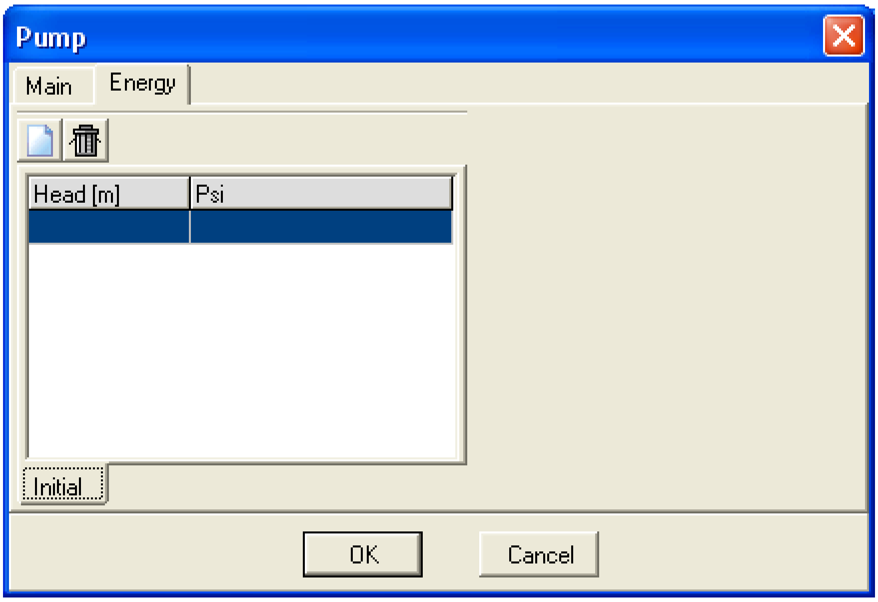
The energy consumption for the operation of the pump varies in conjunction with the head, i.e. the difference of height between the upstream and downstream junction or reservoir. In this case, the energy consumption is given by the following formula:

$$E = y\ V\ Dh$$

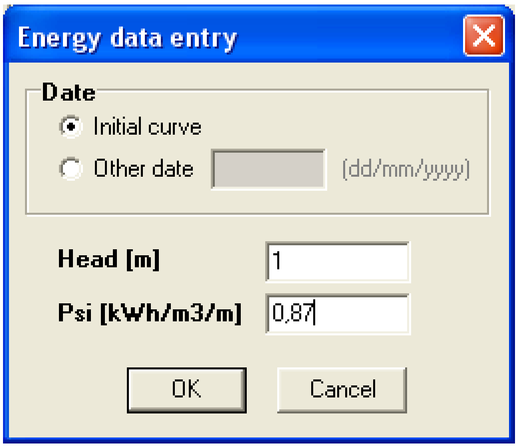
where V is the volume of water passing through the pump and Dh is the head. The energy consumption is expressed in GWh, and the value of y coefficient in GWh/hm^4, and it is by default **higher** than the theoretical quantity of 0.2725 (this value corresponds to zero energy losses and to unit pump performance coefficient).

The y coefficient in conjunction with head is set as follows:

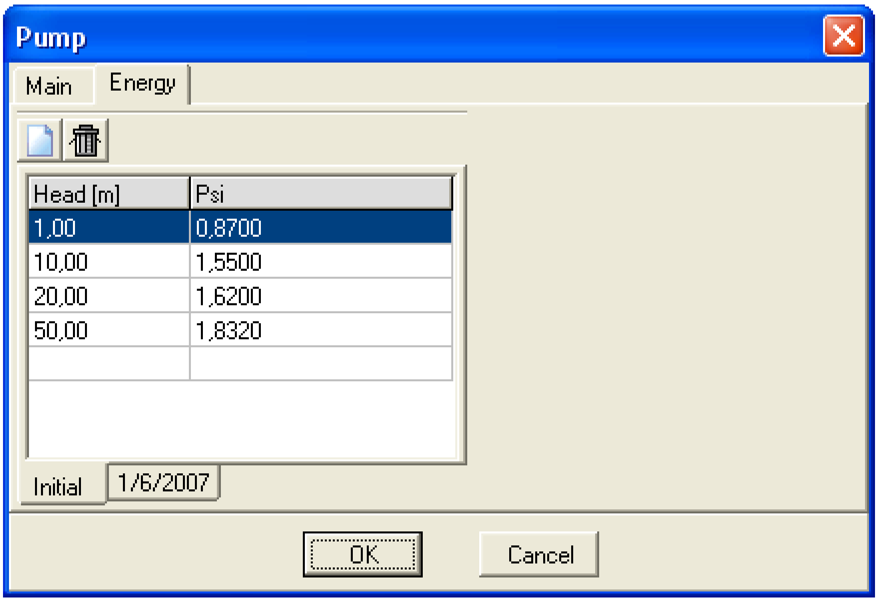
1. In the pump form, select the **Energy** sheet.



2. Click on the **new record** icon or double-click on the last (empty) line of the table.
3. In the energy data input form, enter the **Head** field in m and the specific energy (**Psi)** coefficient in kWh/m^3/m.



4. Confirm the values by clicking **OK**.
5. Repeat the last steps until the head-y coefficient curve is configured. The table lists the records classified as to the head.



Notes:

- If the difference of height upstream and downstream the pump is constant (this applies in case where the pump is not connected with a reservoir), then the head will be constant, and the user sets a single value for the y coefficient.
- If, from the energy data input form, another date is entered, by selecting **other date,** then the values of the y coefficient shall apply as from this date on. Data are entered in a new sheet that lists the start date.
- You cannot record two different y coefficient values for the same head and the same start date.

To delete a record:

1. select the line in the y values table.
2. click the **Delete** icon.

3.1.8 Turbine

In HYDRONOMEAS model, **turbine** means a hydroelectric power production unit that carries water from one point of the network to another. A turbine is represented in the model as an aqueduct with additional characteristics used to calculate power production.

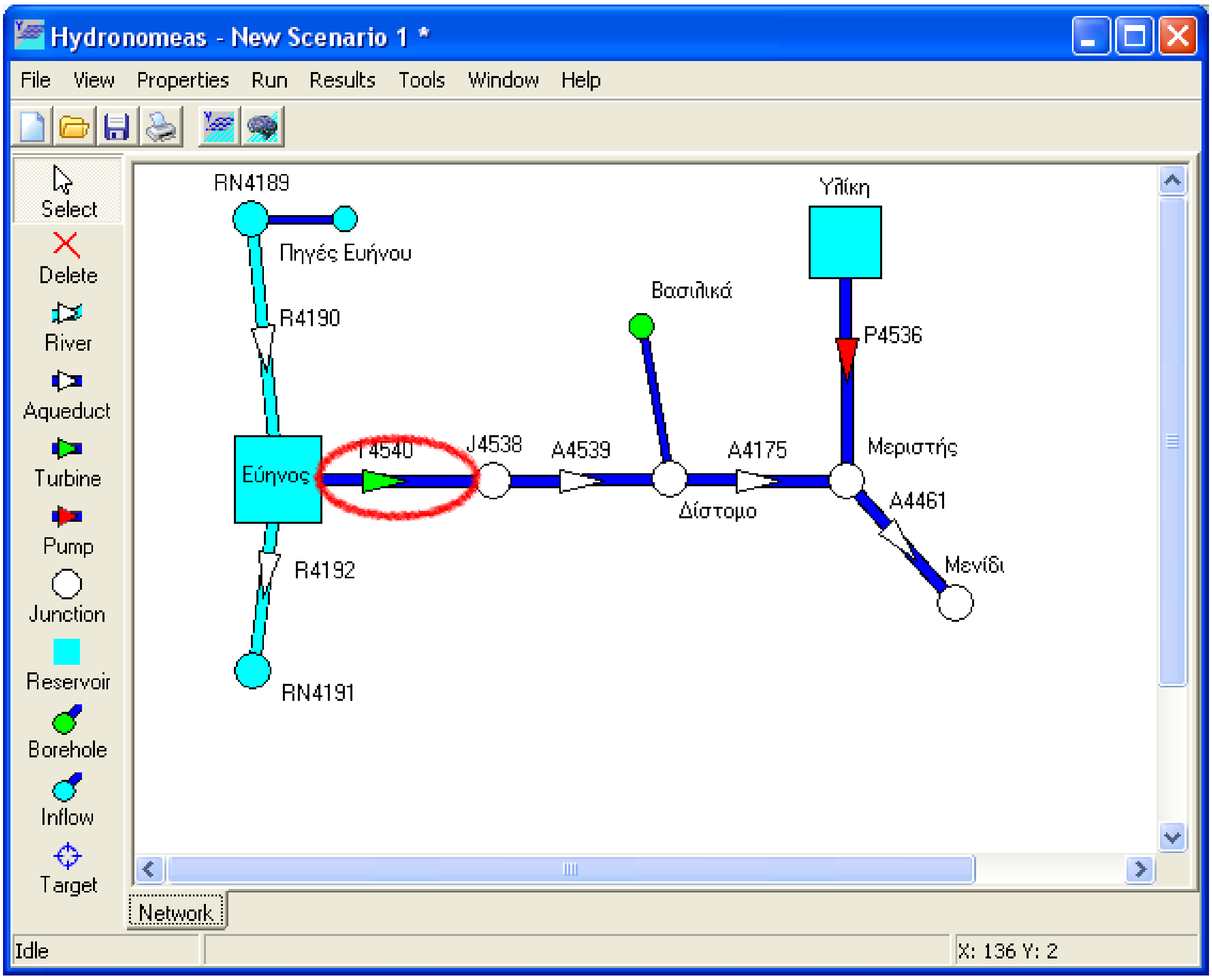
Inserting a new turbine

Similarly to an aqueduct, the turbine as a dependant component of a network is defined by the network's upstream and downstream components, which can include the following:

- Junction
- River node
- Reservoir

A turbine is created as follows:

1. Click the **Turbine** button from the network design tools
2. Then consecutively click on two of the above components on the network's design area.



Modifying a turbine's data

Insertion of a turbine is initially made without having set its properties or with some temporary values for some of them (e.g. name). The properties can be modified by double-clicking on the turbine in the network design area.

The turbine data form is similar to the aqueduct data form, with only difference that:

- turbines do not have leaks in the model and thus there is no provision in the form for entering a leak coefficient value and
- energy production is defined based on a specific energy coefficient **(y coefficient)** from the **Energy** sheet.

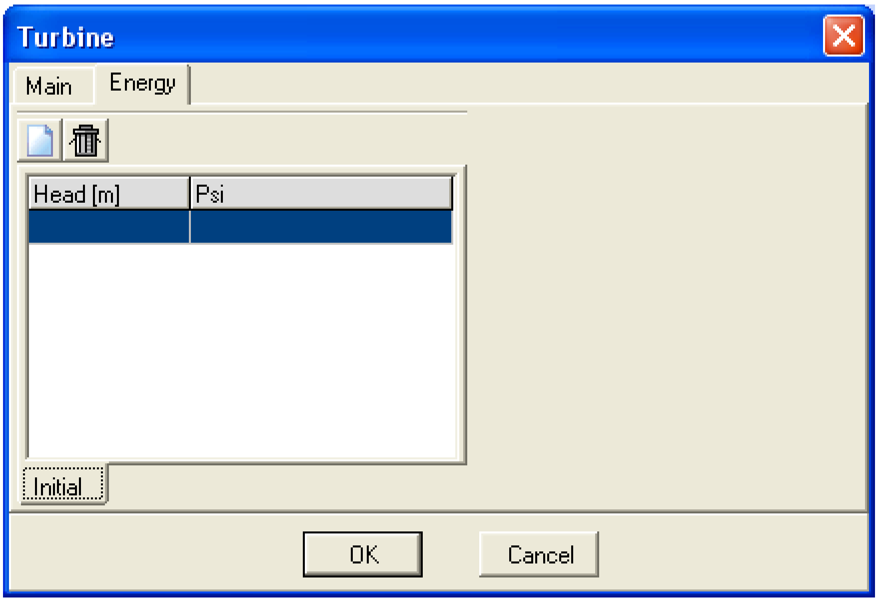
The energy production when water passes through the turbines varies in conjunction with the head, i.e. the difference of height between the upstream and downstream junction or reservoir. In this case, the energy production is given by the following formula:

$$E = y\ V\ Dh$$

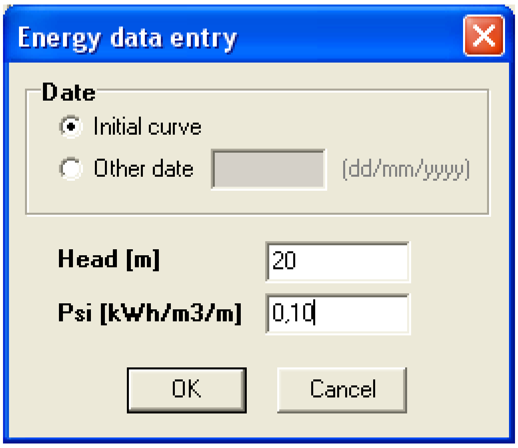
where V is the volume of water passing through the turbine and Dh is the head. The hydroelectric energy production is expressed in GWh, and the value of y coefficient in GWh/hm^4, and it is by default **lower** than the theoretical quantity of 0.2725 (this value corresponds to zero energy losses and to unit turbine performance coefficient).

The y coefficient in conjunction with head is set as follows:

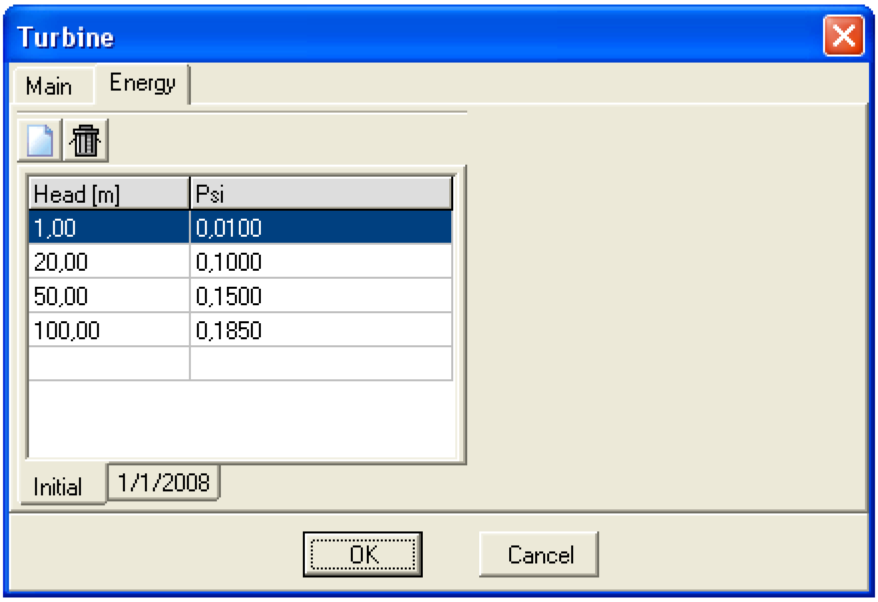
1. In the turbine form, select the **Energy** sheet.



2. Click on the **new record** icon or double-click on the last (empty) line of the table.
3. In the energy data input form, enter the **Head** field in m and the specific energy (**Psi)** coefficient in $kWh/m^3/m$.



4. Confirm the values by clicking **OK**.
5. Repeat the last steps until the head-y coefficient curve is configured. The table lists the records classified as to the head.



Notes:

- ➲ If the difference of height upstream and downstream the turbine is constant (this applies in case where the turbine is not connected with a reservoir), then the head will be constant, and the user sets a single value for the y coefficient.
- ➲ If, from the energy data input form, another date is entered, by selecting **other date,** then the values of the y coefficient shall apply as from this date on. Data are entered in a new sheet that lists the start date.
- ➲ You cannot record two different y coefficient values for the same head and the same start date.

To delete a record:

1. select the line in the y values table.
2. click the **Delete** icon.

3.1.9 River

A river segment object is a conduit with natural flow, e.g. a part of a river.

Inserting a river

A river as a dependant component of a network is defined by the network's upstream and downstream components, which can include the following:

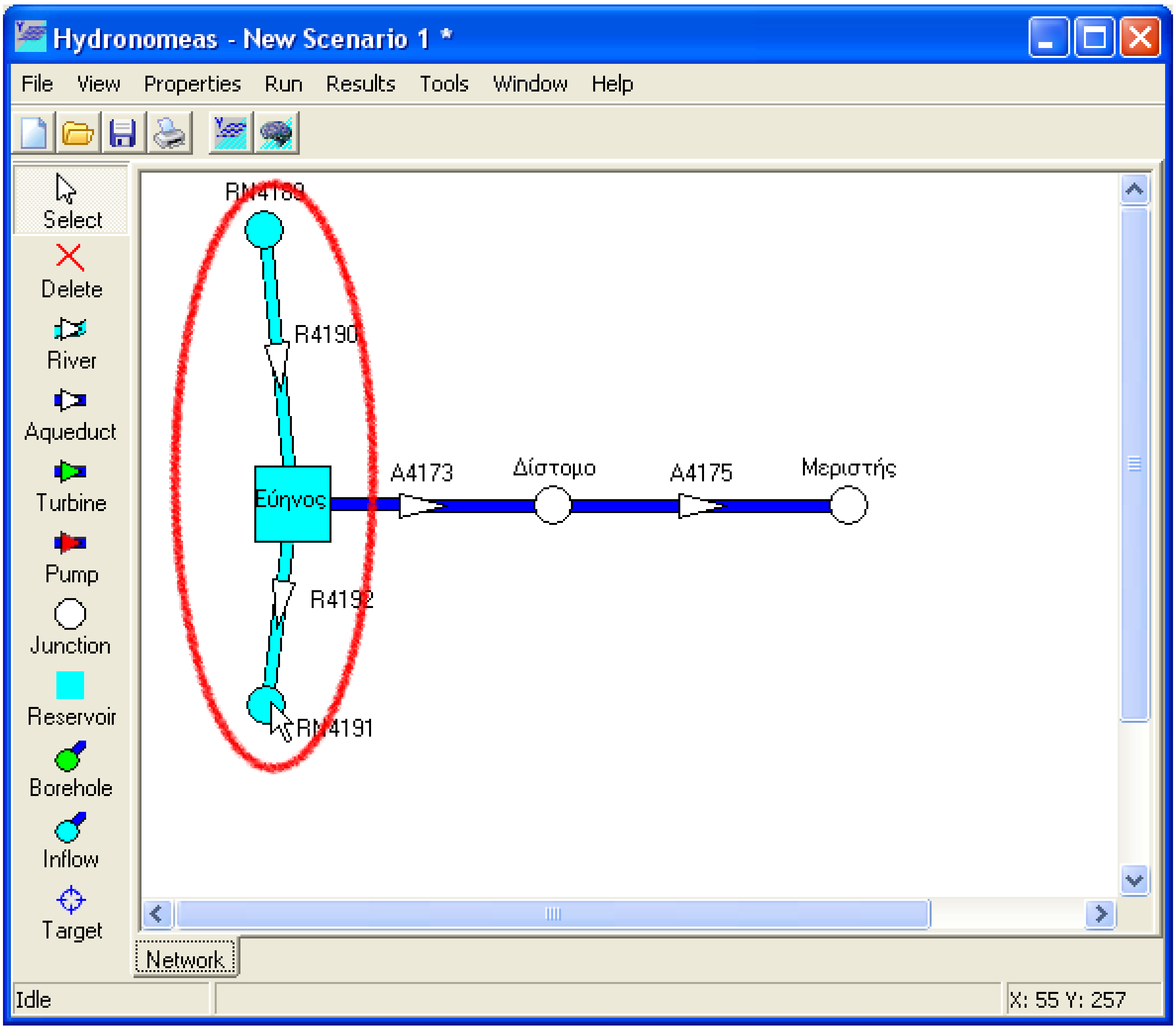
- ➲ River node
- ➲ Reservoir

A river is created as follows:

1. Click the **River** button from the network design tools
2. Then consecutively click on two of the above components on the network's

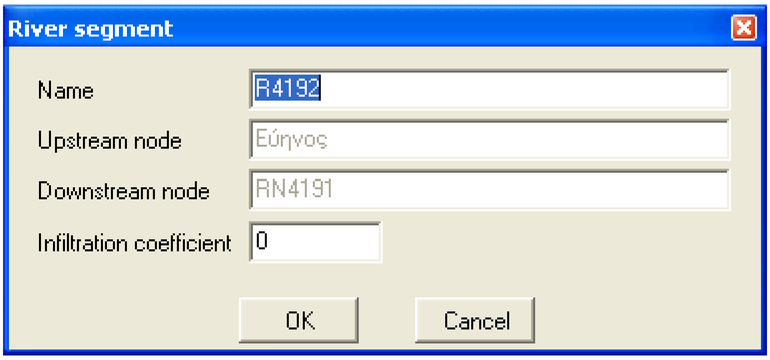
design area. If you select, in the place of a connection component, an empty part of the network design area, a junction is automatically created on this part, with which the river is connected.

3. If you continue to click on the network design area, additional conduits are consecutively created in the form of polylines.



Modifying a river's data

Insertion of a river is initially made without having set its properties or with some temporary values for some of them (e.g. name). The properties can be modified by double-clicking on the river in the network design area.



The river data form lists the following information:

- The **Name** of the river.
- The **Upstream node** and **Downstream node** throught which the river is connected to the network. The user cannot modify the connection components and therefore these fields are displayed inactive.
- The **Infiltration coefficient** that takes actual values from 0..1.

Note: The discharge capacity of rivers is considered to be unlimited.

3.1.10 Borehole

Borehole

Boreholes connect an aquifer with the surface network of the hydrosystem. In the model, a borehole is an entity that can actually be composed of a set of boreholes and thus the borehole in the model receives their aggregate characteristics.

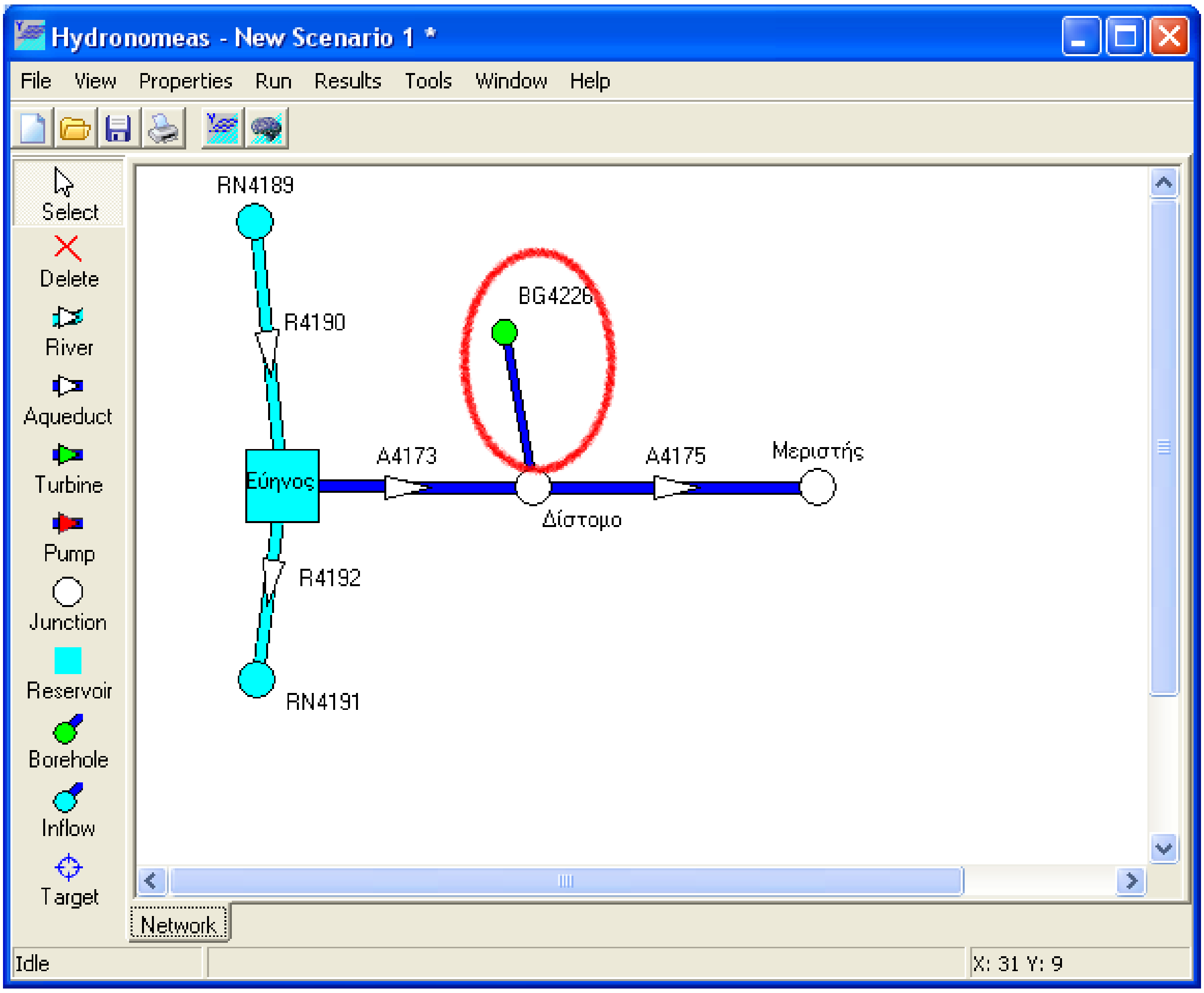
Inserting a new borehole

A borehole as a dependant component of the network can be connected to it only through one of the following components:

- Junction
- River node
- Reservoir

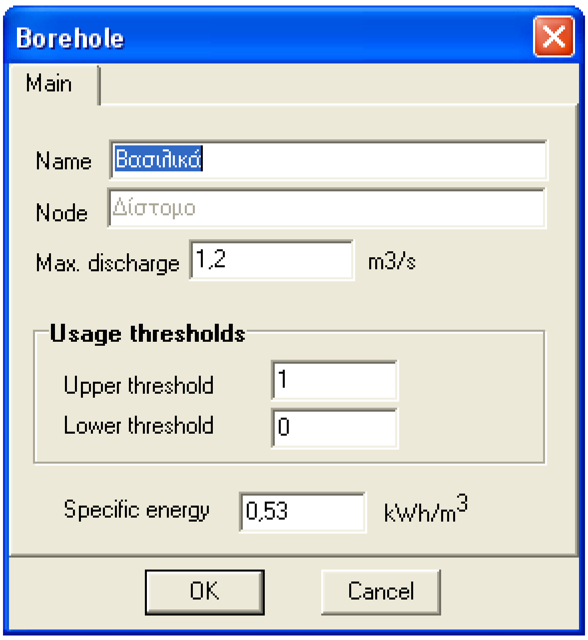
A borehole is created as follows:

1. First click the **Borehole** button from the network design tools
2. Then click on one of the above components on the network's design area.



Modifying a borehole's data

Insertion of a borehole is initially made without having set its properties or with some temporary values for some of them (e.g. name). The properties can be modified by double-clicking on the borehole in the network design area.



The borehole data form lists the following information:

- The **Name** of the borehole.
- The component with which the borehole is connected to the network **(Node)**. The user cannot modify the connection component and therefore this field is displayed inactive.
- The **Maximum discharge** in m^3/s. In case of a set of boreholes, the field displays the aggregate discharge capacity.
- The **Upper threshold** and **Lower threshold** coefficient fields take values from 0 to 1 and concern the borehole's operating mode during simulation (see borehole operating rules).
- The **Specific energy** in kWh/m^3 that represents the energy consumption required for pumping one cubic meter of water from the aquifer.

3.1.11 Inflow

Inflow corresponds to a water discharge time series in the hydrosystem. The inflow can actually represent:

- a spring with known monthly discharge.
- a known runoff from the upstream part of the hydrosystem that needs not to be modeled.

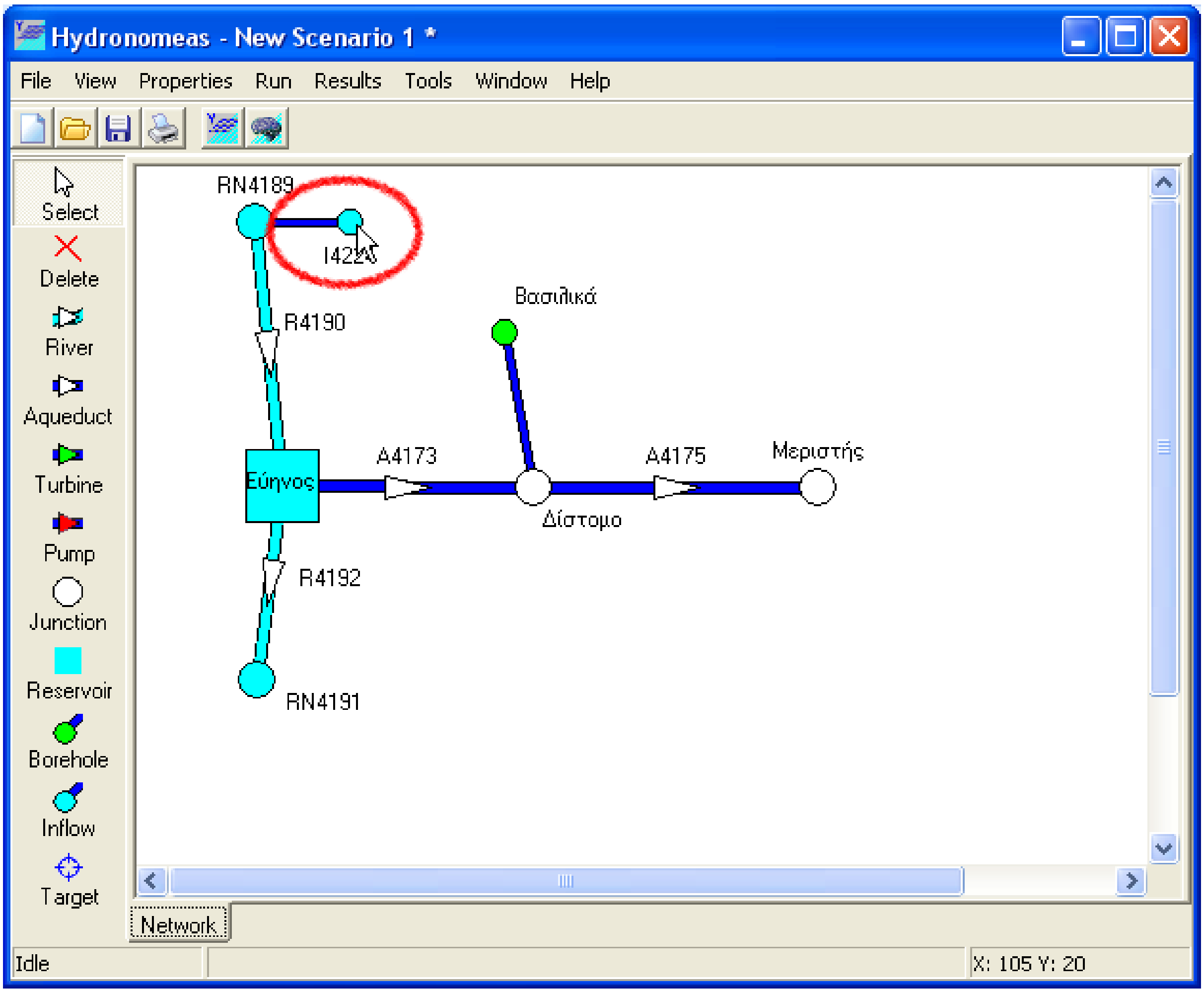
Inserting a new inflow

An inflow as a dependant component of the network can be connected to it only through one of the following components:

- River node
- Reservoir

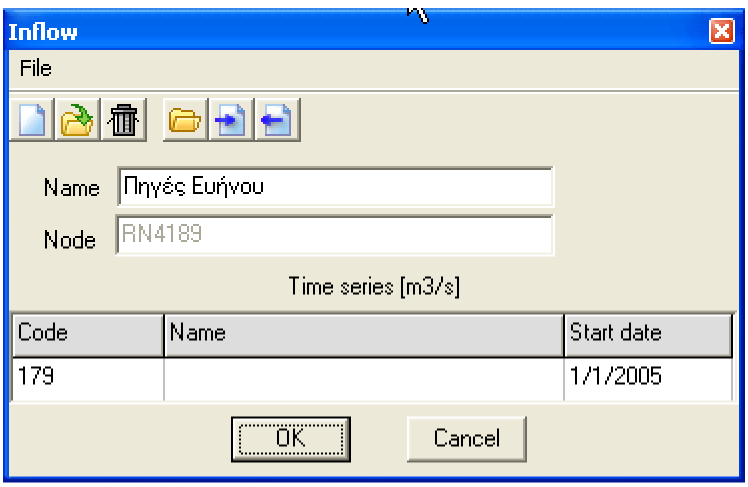
An inflow is created as follows:

1. First click the **Inflow** button from the network design tools
2. Then click on one of the above components on the network's design area.



Modifying inflow data

Insertion of an inflow is initially made without having set its properties or with some temporary values for some of them (e.g. name). The properties can be modified by double-clicking on the inflow in the network design area..



The inflow data form lists the following information:

- The **Name** of the inflow.

- The component with which the inflow is connected to the network **(Node)**. The user cannot modify the connection component and therefore this field is displayed inactive.
- The details of time series that the inflow represents:
  1. time series **Code**.
  2. time series **Name**.
  3. time series **Start date**.

Managing an inflow time series

For the management of time series data, the following actions are available either by selecting **file/...** from the menu or through the relevant icons of the form:

- Create a new time series **(New...)**. From the form displayed, it is possible to create a new time series with multiple modules (see Editing Time Series Data).
- Edit a times series **(Edit...)**. From the form displayed, it is possible to edit a time series (see Editing Time Series Data).
- Delete a time series **(Delete)**.
- Open from the database **(Open...)**. A relevant form is displayed through which, the user can search and select a time series from the database (see Importing Time Series from the database).
- Import from file **(Import...)**. A dialog form appears for selecting and importing a time series file.
- Export in file **(Export...)**. A dialog form appears for exporting a time series in a file.

Note: Saving a time series in the database is made when saving the entire scenario.

3.1.12 Target

HYDRONOMEAS is able to take multiple targets and functional restrictions into account at the same time, which may be competitive against each other. For achieving the targets and restrictions, the computer system does not require the user to predetermine the water transport way or the allocation of water resources in the network. Conversely, the water transport algorithm of the computer system allocates into every simulation time step the required volume, by reassessing the quantity abstracted from each water resource and its way of transport to the water use points in the best possible way. The algorithm autonomously identifies the water discharges based on the network's state, the operating rules and the targets set by the user. For this reason, all targets are included in a system of priorities that is set by the user. During the simulation, HYDRONOMEAS serves (if possible) the targets in order of priority. In case where it is not possible to fully serve a specific target in a time step (month), then **failure** to serve this target for the time step is established.

The categories of targets that can be set and the network components to which they are connected are listed in the following table.

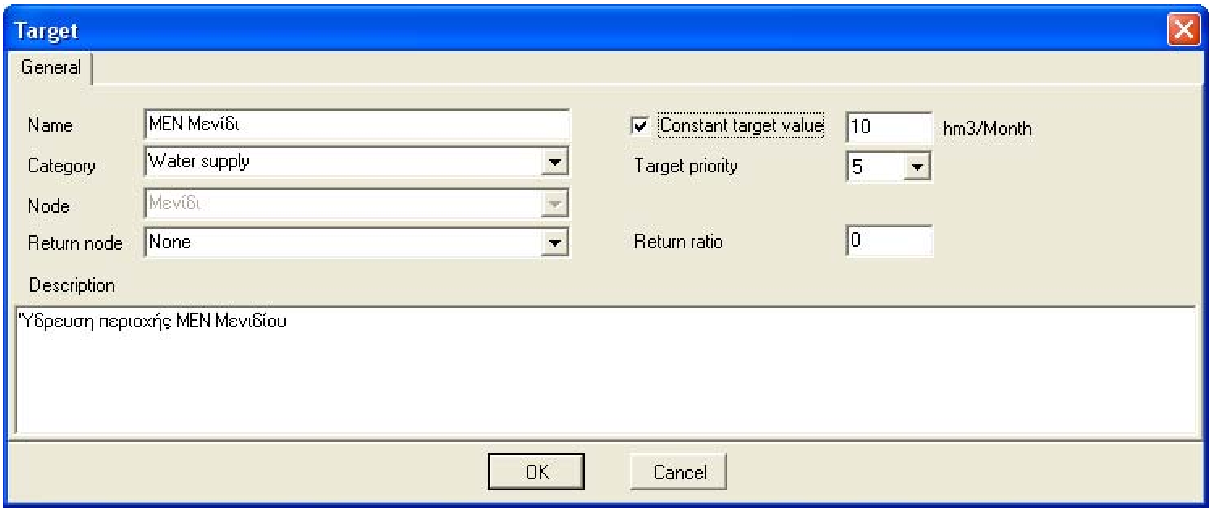
Target category	**Network component**
Water demand for consumption (water supply, irrigation, etc.)	Junction/Reservoir
Maximum, minimum or constant aqueduct flow	Aqueduct
Maximum or minimum reservoir storage	Reservoir
Avoidance of reservoir spill	Reservoir
Hydroelectric power generation	Turbine

A network's component can be connected to more than one water consumption targets, while in the remaining categories, connection of only one target by category is permitted. Obviously, the design of a network model must precede the setting of targets.

Inserting a target

A target is created as follows:

1. First click the **Target** button from the network design tools of the main form.
2. Then click on a component of the network design area to which the target will be connected.
3. The configured target data form is forthwith displayed as follows:



The form includes the following information:

- The name of the target (**Name)**.
- The target category **(Category)** selected from the drop-down menu. Depending on the selection of network component to which the target will be connected, the menu includes part of the following target categories:
    - Water consumption for irrigation **(Irrigation)**.

  - o Water consumption for water supply **(Water supply)**.
  - o Minimum flow of aqueduct **(Min. flow)**.
  - o Maximum flow of aqueduct **(Max. flow)**.
  - o Constant flow of aqueduct **(Const. flow)**.
  - o Minimum volume of reservoir **(Min. volume)**.
  - o Maximum volume of reservoir **(Max. volume)**.
  - o Avoidance of reservoir spill **(No spill)**.
  - o Hydroelectric power generation **(Power generation)**.
- ➲ Network component to which the target **(Node, Conduit, Turbine)** is connected, depending on the category of target. This field appears inactive.
- ➲ Water consumption targets can be assigned a node to which part of the water returns after having been used **(Return node)**. The water **Return ratio** takes values from 0..1. All possible network component options are listed in the drop-down menu that includes all the network's nodes (aqueduct junctions, river nodes and reservoirs). In case where water is totally consumed and does not return to the system, then select **None** from the menu**.**
- ➲ The target priority **(Target priority)** set.
- ➲ The **Constant target value**. For selecting the constant target value, you must activate the relevant label and enter the target value in the field.

The measuring units are:

- o for water consumption targets: hm^3
- o for reservoir storage management targets: hm^3
- o for targets of managing water discharge in aqueduct or river: m^3/s.
- o for targets of generating hydroelectrical power in turbines: GWh

The spill avoidance target is undissociated

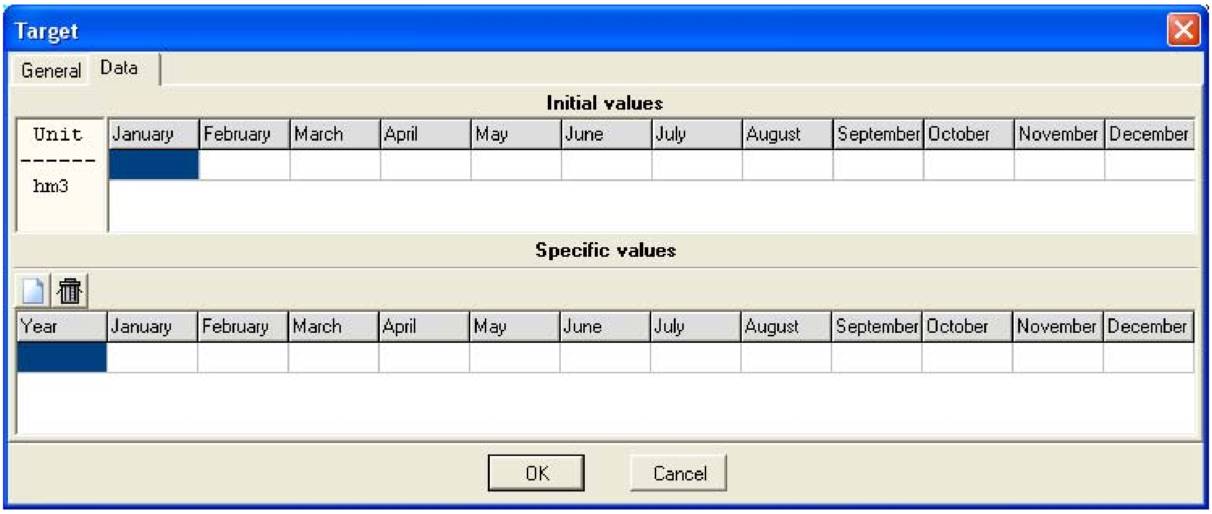
When the option is inactive, the target value is considered as variable in time and its values are set in the variable target value sheet.

Variable target value

HYDRONOMEAS provides the possibility to temporally differentiate a target, in order for the simulation to correspond to different situations, such as increase of water demand, seasonal differentiation of the desirable reservoir level fluctuation range, etc.

Temporally variable target values are defined as follows:

1. In the main sheet of the target data form, deactivate the **Constant target value** option.
2. Select the target data sheet **(data)**.



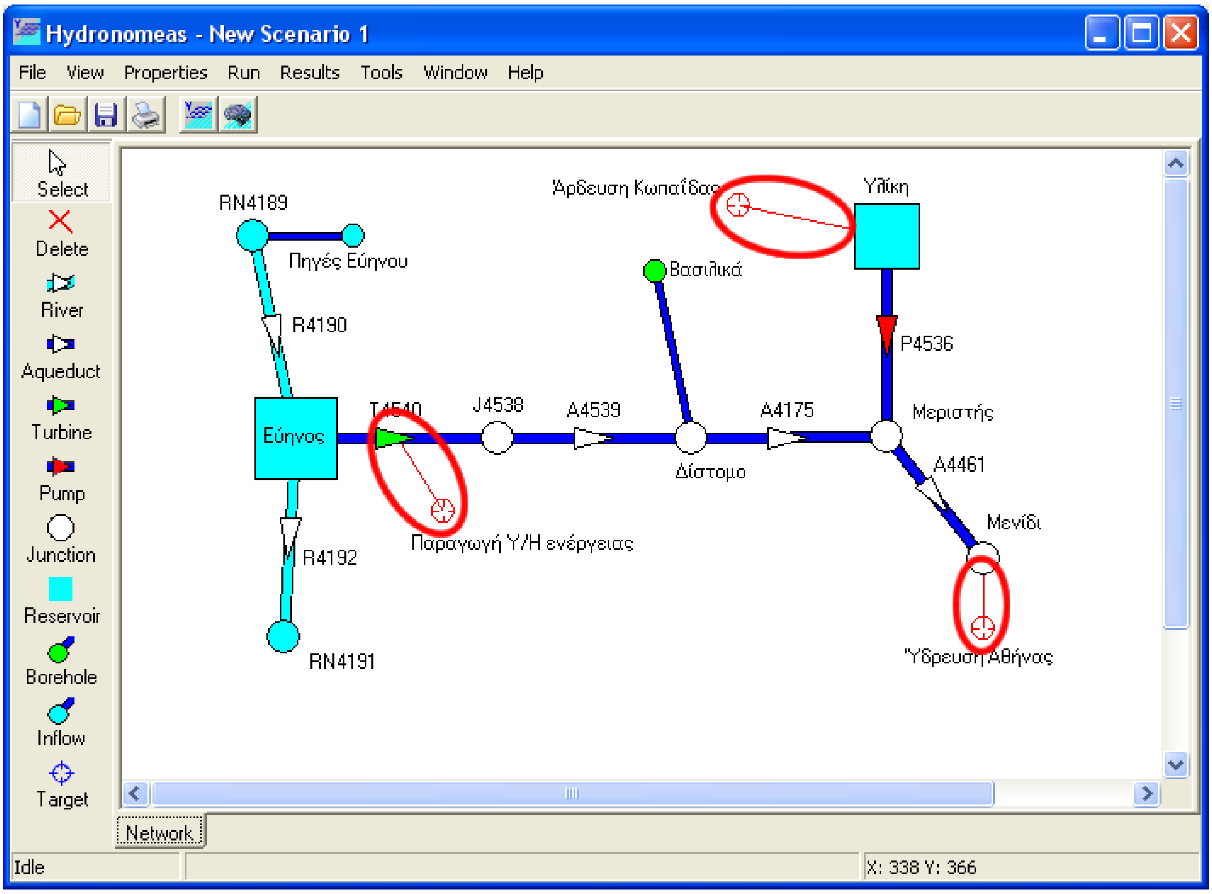
3. In the fields of the **Initial values** table, enter the initial monthly values of the target. These values shall apply from the beginning to the end of the simulation or until replaced by those of the specific values table.
4. In the **Specific values** table enter the monthly values that will apply for specific number of years **(Year** field**)** and thereafter. Every new record in the specific values table replaces the old target values. Using the **New line** icon, enter new lines, and using the **Delete line** icon, delete lines from the specific values table.

The measuring units are listed as reminder in the **Unit** area.

Note: The records in tables must always cover one calendar year, otherwise the values for the specific incomplete year shall not be considered.

Modifying target data

A target's properties can be modified from the target data form which appears by double-clicking on the target's icon in the network design form.



The user can also view the target data form and modify the details or delete a target from the targets list form (see network component tables).

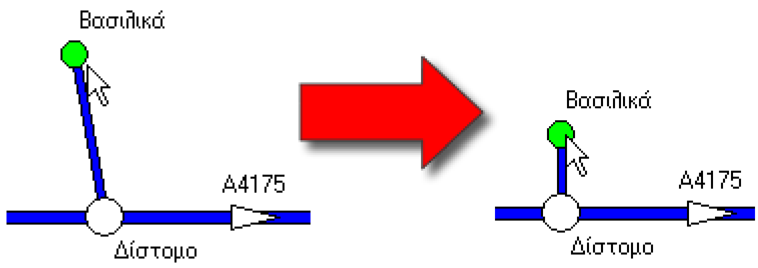
3.1.13 Network design support operations

3.1.13.1 Move and align

Moving a single network component

The symbol of a point network component (node, reservoir, borehole, inflow) can be moved on the network design area as follows:

1. Select the component by clicking on the symbol
2. By holding down the left button of the mouse, you can drag the component to the new position.



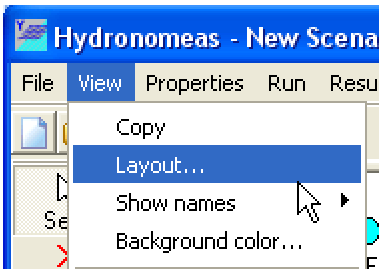
The non-point network components (aqueducts, pumps, turbines, rivers) depend on the upstream and downstream junctions and therefore can only be moved through them.

All network's dependent components (e.g. borehole, inflow) are moved together with the component to which they are connected. Moreover, all the names are moved together with the respective network components.

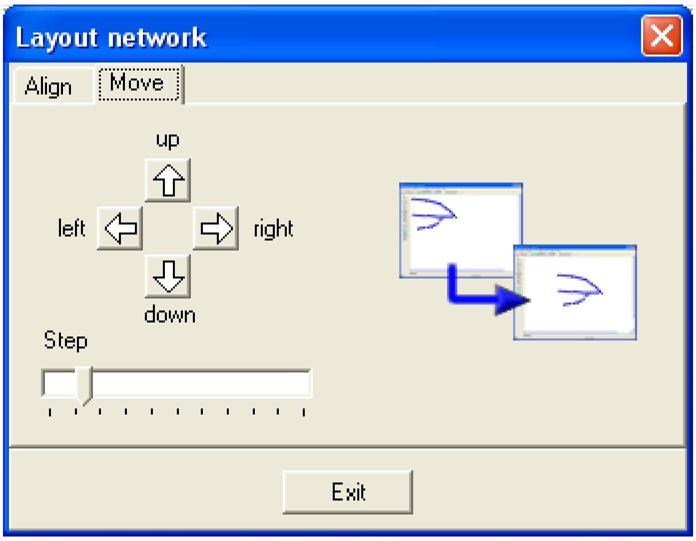
Moving the network

All network components can be moved as follows:

1. Select **View/Layout...** from the Main Form menu.



2. From the form displayed, select the **Move** sheet.

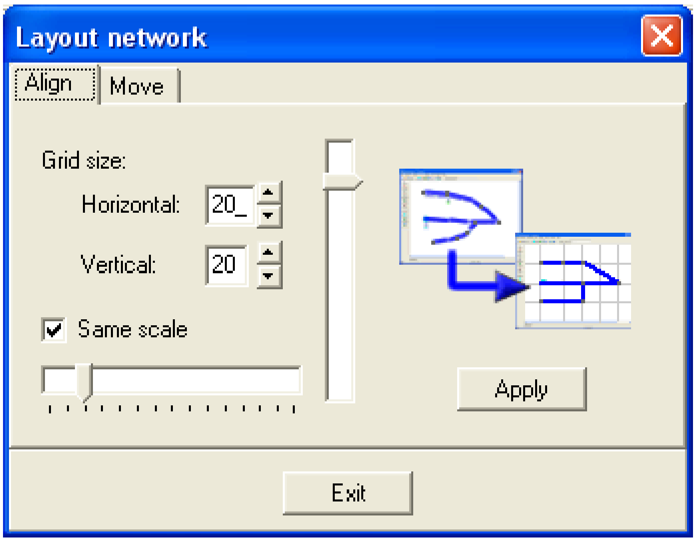


3. Set the desirable Step.
4. Click the button to the displacement direction: up, down, left, right.

Alignment

All network components can be aligned as to an ideal grid as follows:

1. Select View/Layout... from the Main Form menu.
2. From the form displayed, select the Align data sheet.

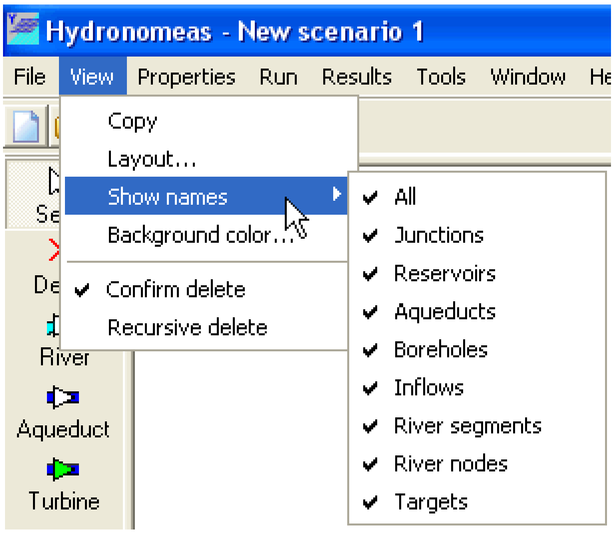


3. Select a common or different grid interval on the horizontal and vertical axis **(Same scale)**.
4. Set the desirable grid interval on the **Horizontal** and **Vertical** axis.
5. Click the **Apply** button for the alignment.

3.1.13.2 Show names

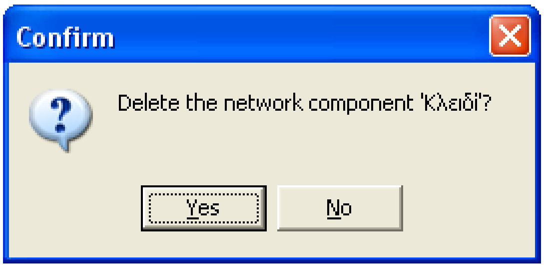
In the network design area, the user can show or hide from the screen the names of network components as follows:

1. Select **View/Show names** from HYDRONOMEAS Main Form menu.
2. From the sub-menu displayed, select one of the following:
   - **All**: Show/hide the names of all network components.
   - **Junctions**: Show/hide the names of all network junctions.
   - **Reservoirs**: Show/hide the names of all network reservoirs.
   - **Aqueducts**: Show/hide the names of all network aqueducts (including pumps and turbines).
   - **Boreholes**: Show/hide the names of all network boreholes.
   - **Inflows**: Show/hide the names of all network inflows.
   - **River segments**: Show/hide the names of all network river segments.
   - **River nodes**: Show/hide the names of all network river nodes.
   - **Targets**: Show/hide the names of all network targets.



3.1.13.3 Confirming a deletion

Before deleting a network component, the user is prompted to confirm its deletion through the following dialog form:



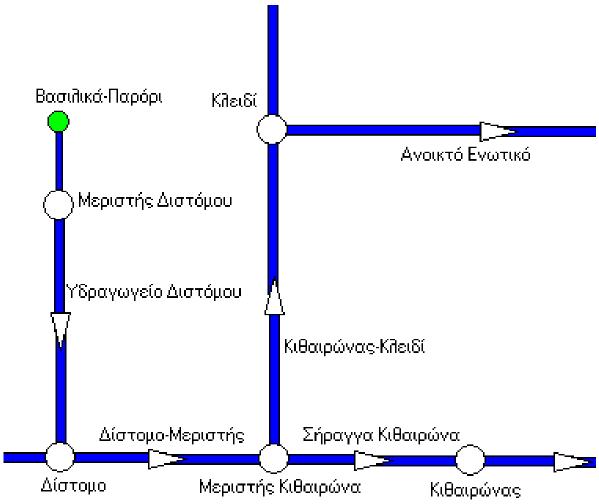
This procedure can be simplified, if the user disables the "Confirm delete" option from the Main Form menu, by selecting **View/Confirm delete**.

3.1.13.4 Recursive delete

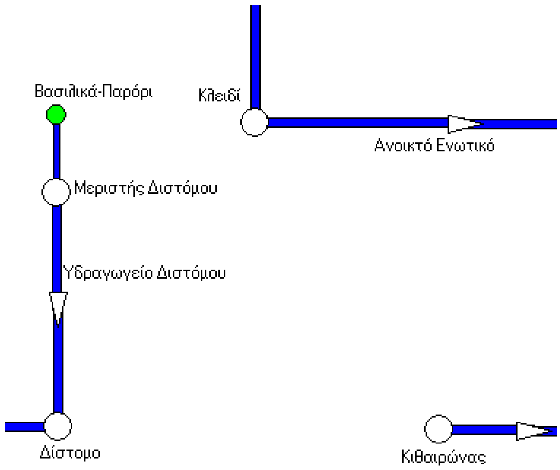
Autonomous network components (junctions, reservoir, etc.) may be connected to certain dependent network components (aqueduct, borehole, etc.). For security reasons, HYDRONOMEAS typically prohibits the deletion of autonomous network components if all their dependent components have not previously been deleted.

Exceptionally, it is possible to delete with a network component all its dependent components during the same process, if the user has previously activated the **Recursive delete** option, by selecting **View/Recursive delete** from the Main Form menu.

Example of recursive delete



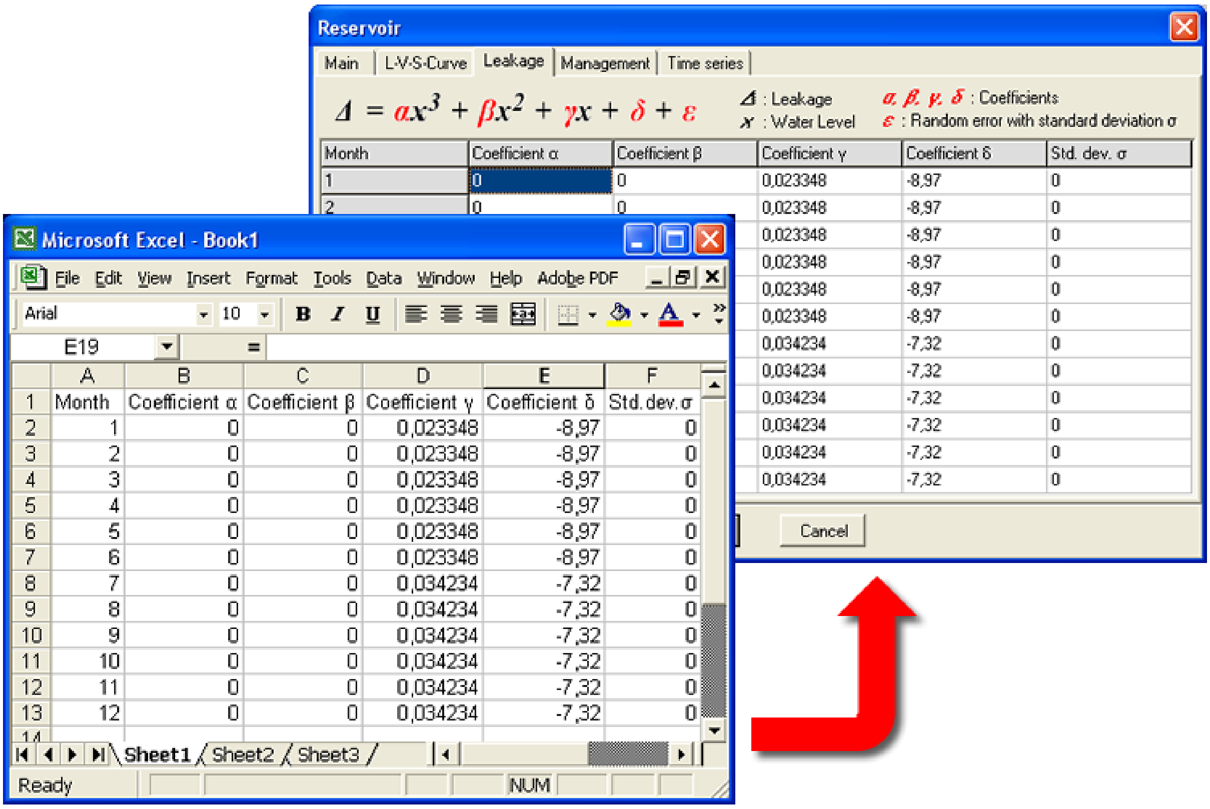
Initial network diagram



Following recursive deletion of "Kitheronas Bifurcation" node

3.1.14 Importing and exporting table data

Sometimes it is necessary to import data from other applications (e.g. Microsoft Excel) or to use data from this application to others. To import and export data to tables, the user can use the copy/paste option or save the data in a CSV file. To perform these actions, select them from the menu displayed by right-clicking on any table.



3.1.14.1 Importing data

In selected tables, you can import data from a table of another application (e.g. Microsoft Excel). Import can be made as with the copy & paste option, as described below:

1. Select the cells to be copied from the first application's table.
2. Select the table cell from where paste shall begin.
3. Right-click on a cell to select **Paste**.

<u>Notes:</u>

Copying of data is limited only to the writable cells of the table.

This operation is not generally available for all tables of the application, but only for selected tables. When this operation is not available, the Paste option appears inactive.

3.1.14.2 Exporting data

Exporting of data from a table of another application (e.g. Microsoft Excel) can be made as with the copy & paste method, as described below:

1. Select the cells to be copied from HYDRONOMEAS table. To select all the

table (together with non-writable cells) select **Select all** from the pop-up menu displayed when you right-click on the table.

2. Right-click on the table to select **Copy**.
3. Paste the data on the second application with the respective option.

Note: For tables where multiple selection of cells is not permitted, data export always refers to the entire table.

3.1.14.3 Exporting a table in a .csv file

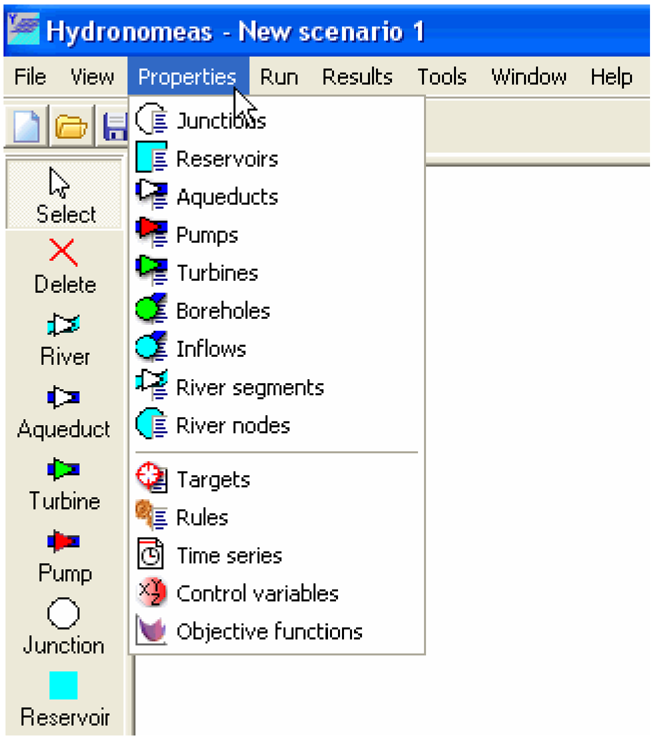
Right-click anywhere on the table and select Save to CSV-file.

1. Search the directory where the data shall be stored and enter the name of the file in the **File name** field.
2. The .csv file can be read from any software which recognizes this format, e.g. Microsoft Excel.

3.2 Scenario Component Tables

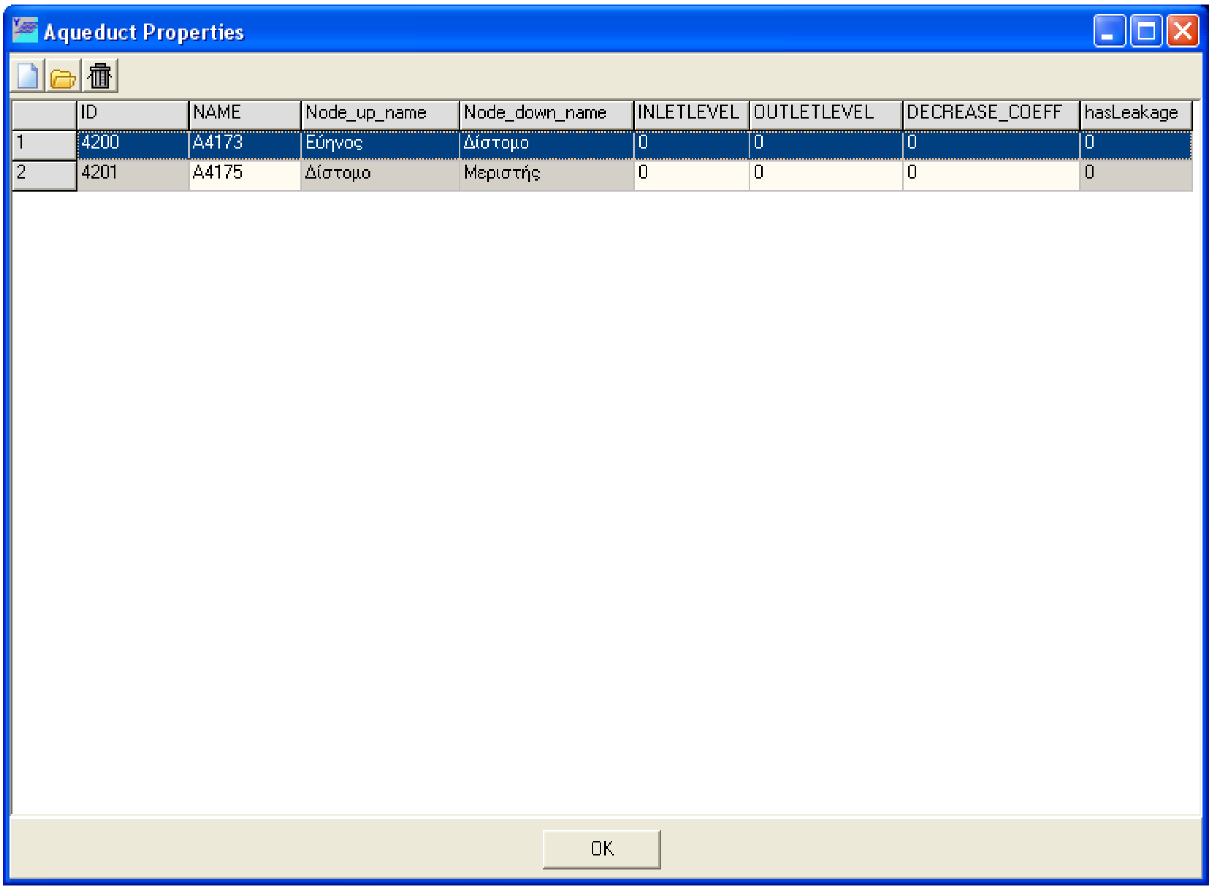
The scenario component tables list the components and their main properties. Selection is made through the **Properties/...** option of the Main Form menu for the following categories:

Junctions:	Aqueduct junctions
Reservoirs:	Reservoirs
Aqueducts:	Aqueducts
Pumps:	Pumps
Turbines:	Turbines
River segments:	River segments
River nodes:	River nodes
Boreholes:	Boreholes
Inflows:	Inflows
Targets:	Targets
Rules:	Operating rules
Time series:	Time series



The form displayed shows the following:

- the **main properties table** of network components. Each line corresponds to a network component, and the columns refer to the component's main properties, such as the name of the component and other properties that depend on the category of the component (see the respective data form of the network component).



- the **operation icons**:
  - **New**: Creates a new component. This operation is supported only for categories: Aqueduct junction, reservoir, target and operating rule.
  - **Open**: Opens the data form of the selected component. The form also opens, by double-clicking on the line that corresponds to the component.
  - **Delete**: Deletes the selected component.
    Warning: This is a "Recursive Delete" operation, i.e. dependent components are deleted as well.

Exceptionally, in the operating rules category, the following additional operations are provided:

- **Reservoirs**: Shows the operating rules reservoir graph form
- **Simulate**: Launches the simulation with the selected operating rules for reservoirs and boreholes

The network's diagram is updated when closing the form.

Part IV

4 Hydrological Scenarios and Time Series

The hydrological variables of the hydrosystem are provided in the form of sequences of known values, i.e. **time series**, which are assigned to selected network components. More particularly, time series are assigned to **reservoirs** and **inflow junctions**.

There are three types of reservoir time series:

- catchment time series
- rainfall time series
- evaporation time series

Catchment refers to the water runoff from the sub-basin upstream the dam, while rainfall and evaporation refer to reservoir's surface. All the values of the above time series are shown in units of equivalent water level (necessarily in mm). On the contrary, time series for inflow junctions are directly given discharge units (m^3/s).

The model's time series can be **historical** (primary or processed) or **synthetic**, which means that they are generated through a stochastic model. In principle, synthetic time series generation models preserve the statistical correlations among the respective hydrological processes, thus assuring that representation of hydrological processes will be realistic and compatible with the actual conditions of the system. The time series generated through such systematic procedure are grouped into **hydrological scenarios**. Therefore, the hydrological scenario refers to a group of synthetic time series which are statistically consistent the one to the other. Obviously, time series that belong to a hydrological scenario have common start date and length.

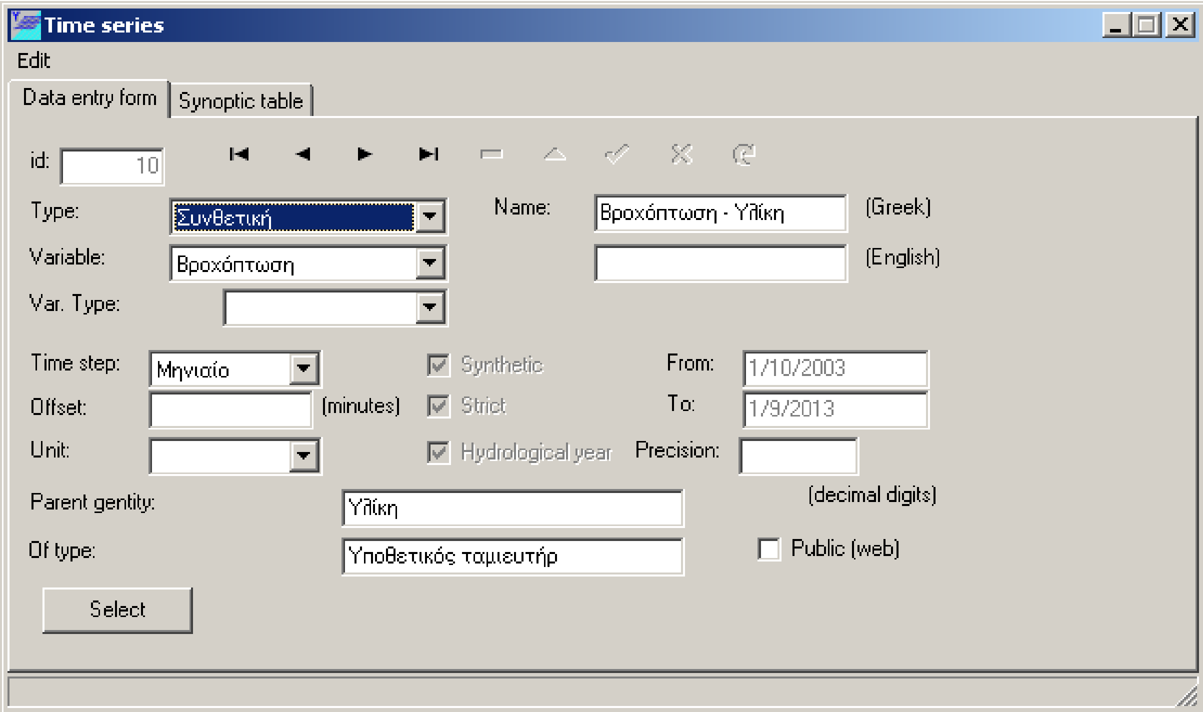
4.1 Importing time series from the Database

HYDRONOMEAS can import time series that are stored in the database through the time series management form displayed in the following ways:

- from the time series sheet of the reservoir data form.
- from the inflow data form.

Time series data processing is made at independent level.

The database time series management form is as follows:



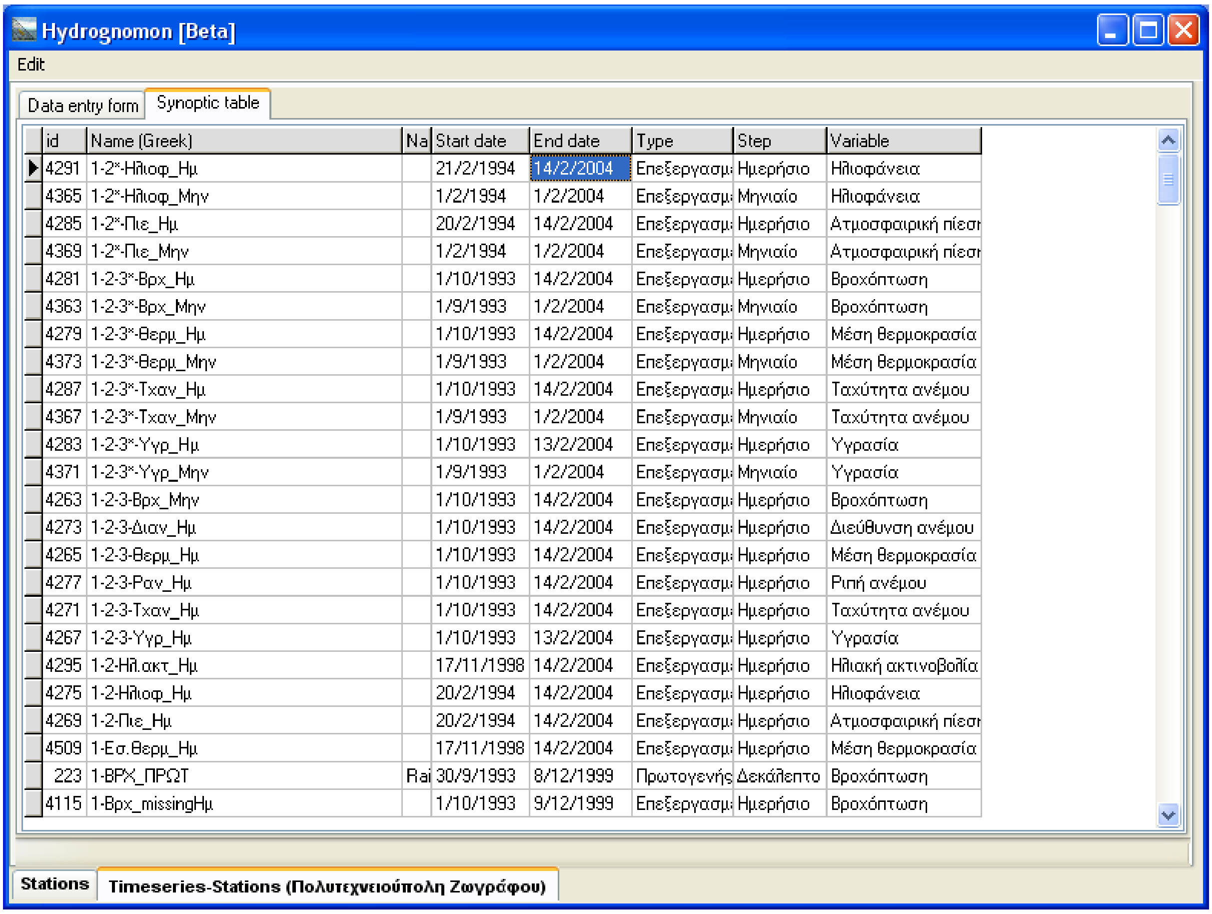
Navigation through the database's documents (time series) is made using the following buttons:

- **first record**: Go to the first time series
- **prior record**: Go to the previous time series
- **next record**: Go to the next time series
- **last record**: Go to the last time series

To import the selected time series from the database, click the **Select** button.

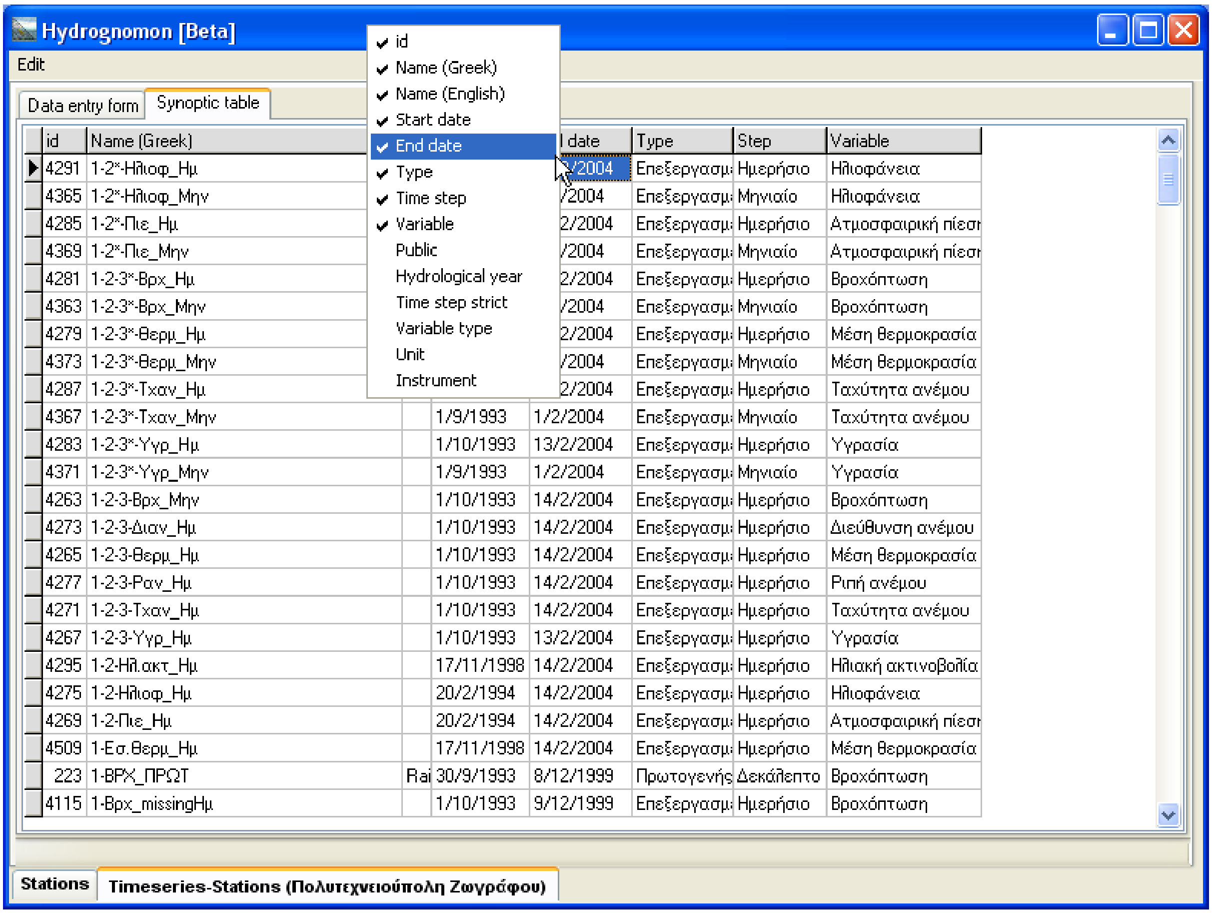
The remaining buttons of the form are disabled, because HYDRONOMEAS cannot modify individual time series in the database (for time series management, see HYDROGNOMON software).

By clicking the **Synoptic table** tab, a full list of time series appears (see the following picture). Clicking on the title of a column (field), time series are classified based on this field.



id	Name (Greek)	Na	Start date	End date	Type	Step	Variable
4291	1-2*-Ηλιοφ_Ημ		21/2/1994	14/2/2004	Επεξεργασμ	Ημερήσιο	Ηλιοφάνεια
4365	1-2*-Ηλιοφ_Μην		1/2/1994	1/2/2004	Επεξεργασμ	Μηνιαίο	Ηλιοφάνεια
4285	1-2*-Πιε_Ημ		20/2/1994	14/2/2004	Επεξεργασμ	Ημερήσιο	Ατμοσφαιρική πίεση
4369	1-2*-Πιε_Μην		1/2/1994	1/2/2004	Επεξεργασμ	Μηνιαίο	Ατμοσφαιρική πίεση
4281	1-2-3*-Βρχ_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Βροχόπτωση
4363	1-2-3*-Βρχ_Μην		1/9/1993	1/2/2004	Επεξεργασμ	Μηνιαίο	Βροχόπτωση
4279	1-2-3*-Θερμ_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Μέση θερμοκρασία
4373	1-2-3*-Θερμ_Μην		1/9/1993	1/2/2004	Επεξεργασμ	Μηνιαίο	Μέση θερμοκρασία
4287	1-2-3*-Ταχαν_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Ταχύτητα ανέμου
4367	1-2-3*-Ταχαν_Μην		1/9/1993	1/2/2004	Επεξεργασμ	Μηνιαίο	Ταχύτητα ανέμου
4283	1-2-3*-Υγρ_Ημ		1/10/1993	13/2/2004	Επεξεργασμ	Ημερήσιο	Υγρασία
4371	1-2-3*-Υγρ_Μην		1/9/1993	1/2/2004	Επεξεργασμ	Μηνιαίο	Υγρασία
4263	1-2-3-Βρχ_Μην		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Βροχόπτωση
4273	1-2-3-Διαν_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Διεύθυνση ανέμου
4265	1-2-3-Θερμ_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Μέση θερμοκρασία
4277	1-2-3-Ριαν_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Ριπή ανέμου
4271	1-2-3-Ταχαν_Ημ		1/10/1993	14/2/2004	Επεξεργασμ	Ημερήσιο	Ταχύτητα ανέμου
4267	1-2-3-Υγρ_Ημ		1/10/1993	13/2/2004	Επεξεργασμ	Ημερήσιο	Υγρασία
4295	1-2-Ηλ.ακτ_Ημ		17/11/1998	14/2/2004	Επεξεργασμ	Ημερήσιο	Ηλιακή ακτινοβολία
4275	1-2-Ηλιοφ_Ημ		20/2/1994	14/2/2004	Επεξεργασμ	Ημερήσιο	Ηλιοφάνεια
4269	1-2-Πιε_Ημ		20/2/1994	14/2/2004	Επεξεργασμ	Ημερήσιο	Ατμοσφαιρική πίεση
4509	1-Εσ.Θερμ_Ημ		17/11/1998	14/2/2004	Επεξεργασμ	Ημερήσιο	Μέση θερμοκρασία
223	1-ΒΡΧ_ΠΡΩΤ	Rai	30/9/1993	8/12/1999	Πρωτογενής	Δεκάλεπτο	Βροχόπτωση
4115	1-Βρχ_missingΗμ		1/10/1993	9/12/1999	Επεξεργασμ	Ημερήσιο	Βροχόπτωση

The columns shown in the time series synoptic table can be configured by the user: By right-clicking on the column titles (see the following picture), all columns appear in a list and with an indication on the visible columns. Moreover, by “dragging” the columns, you can change the display order. Finally, one can also change the size of a column.



4.1.1 Time series fields

In the **data entry form** tab, the following time series details are displayed:

Name: The name of a time series, a free descriptive text field.

From - To: The time limits of a time series. These fields are automatically updated from the actual data comprised in the time series.

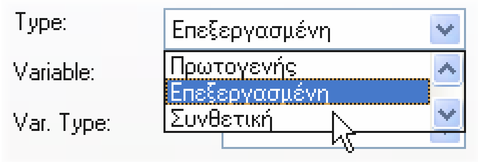
Synthetic: This label is automatically activated for synthetic data time series.

Strict: Strict time step. The strict time step refers to time series where values are temporally equidistant. The strict time step does not however exclude a constant Date offset, for example daily rainfall measurements at 08:00 instead of 00:00 when day begins. The **Strict** property can only be set in time series of ten-minutes, hourly and daily time step. For time series of monthly and yearly time step, this property by default is active.

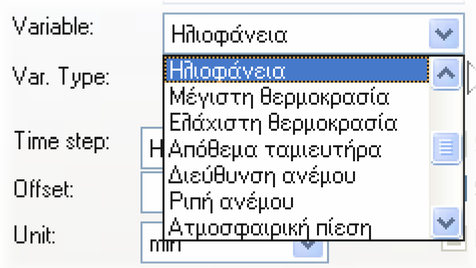
Date offset: Temporal offset, if a time series has strict time step and values do not refer to the integer temporal segmentations (e.g. beginning of an hour or day) the quantity of constant date offset must be determined, mainly for internal checks of data consistency.

Hydrological year: This property is meaningful only for time series with yearly time step.

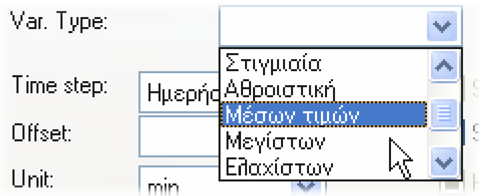
Type: A time series can include primary measurement data, processed data or can be a synthetic time series produced by a generation model. After having determined the type of data, it can no longer be changed. HYDRONOMEAS can load any type of time series from the database, but time series stored in the database (together with a HYDRONOMEAS scenario) are always of synthetic type.



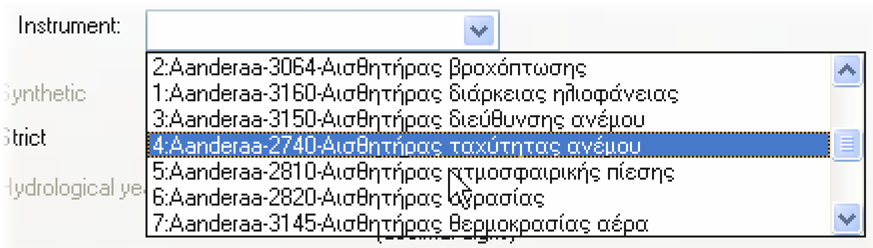
Variable. The variable field provides the hydrometeorological variable of time series data, e.g. temperature, moisture, wind speed, etc.



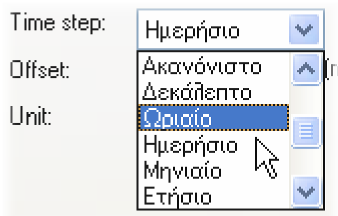
Variable type (The type of processed time series variable). The processed time series may have been obtained as maximum, instant, minimum or mean values from the data of an initial time series. The label appears in this field **(Var. Type)**.



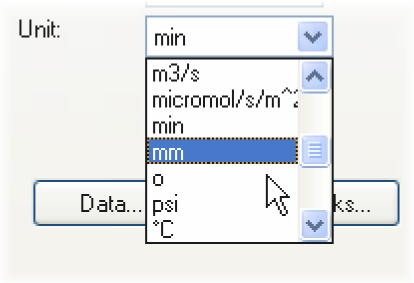
Instrument: Specifically the time series of gauging stations are also organized as to their instruments.



Time step: The type of a time step.

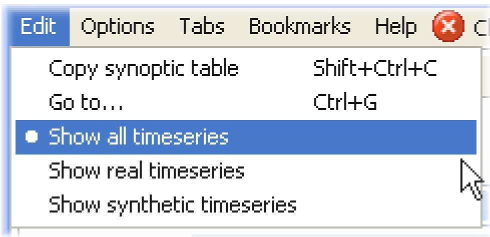


Unit (Measuring unit): The time series data are expressed in some physical quantity which is shown in this field.

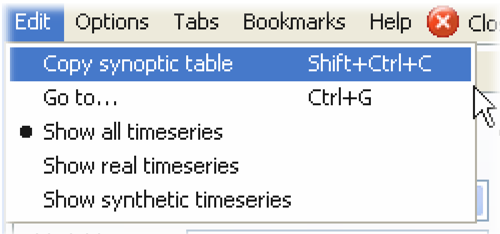


4.1.2 Special operations

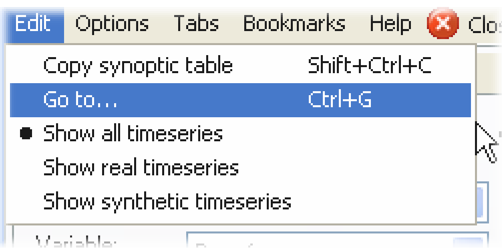
Show all timeseries **(Show all timeseries)** or only the synthetic **(Show synthetic timeseries)** or the real ones **(Show real timeseries)**. Real time series are the time series of primary or processed data. The user uses the menu below from the time series management form:



- Copy the synoptic table to clipboard (Copy synoptic table). The user can copy the records as they are shown in the synoptic table:



- Go to a specific record with known id (**Go to...**):

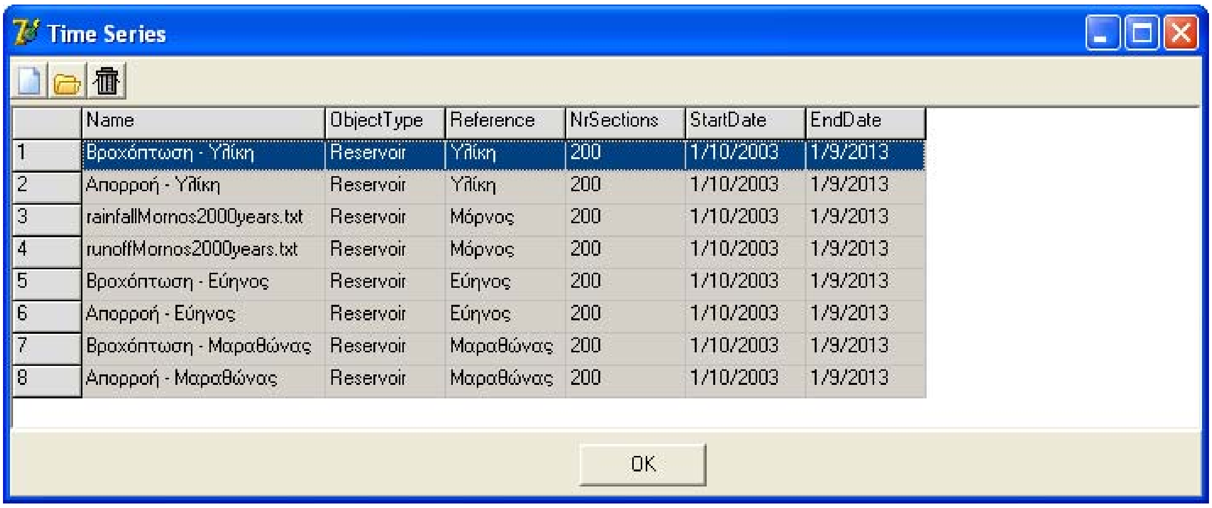


4.2 Editing time series data.

HYDRONOMEAS can edit time series through the time series management form displayed in the following ways:

➲ from the time series sheet of the reservoir data form.

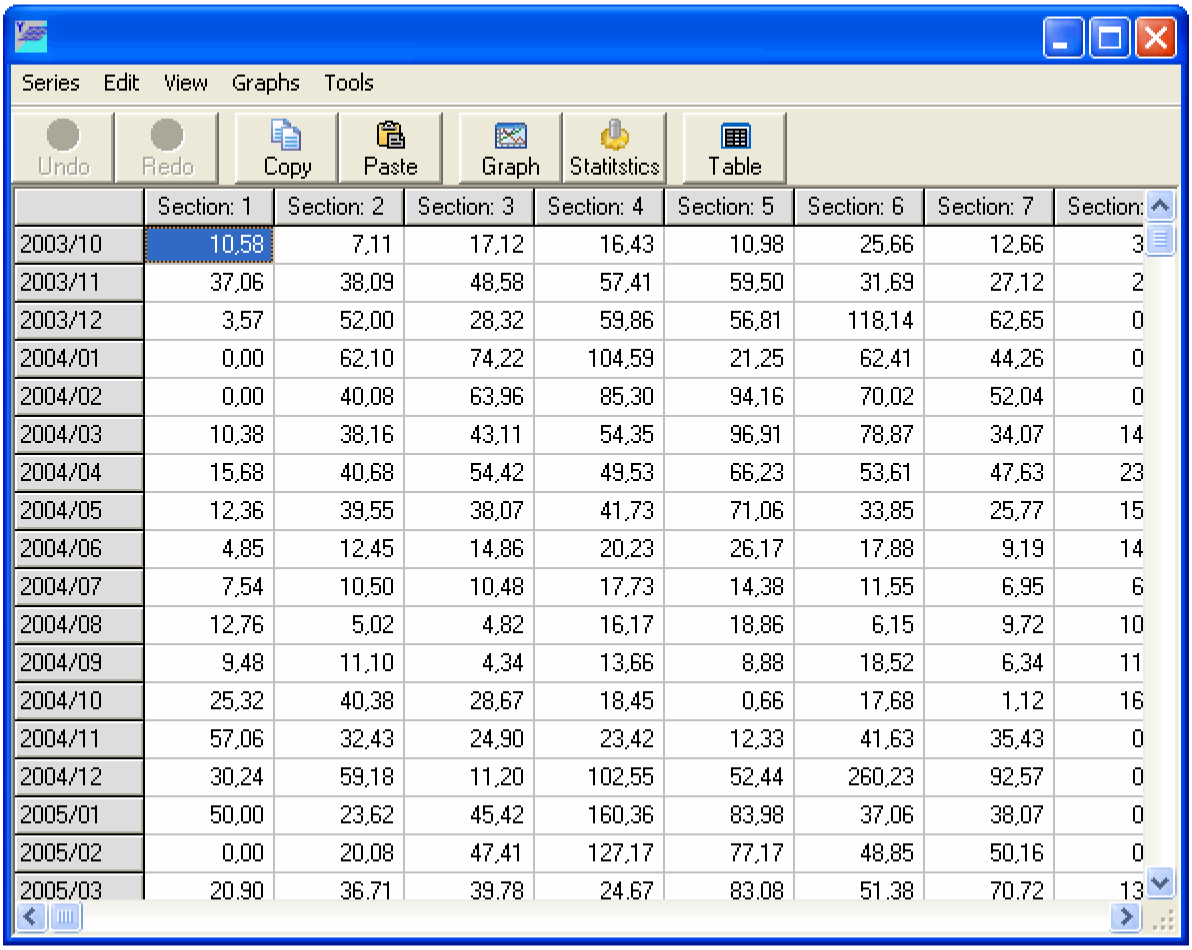
- from the inflow data form.
- from the time series table by selecting **Properties/Time series** from HYDRONOMEAS main form.



	Name	ObjectType	Reference	NrSections	StartDate	EndDate
1	Βροχόπτωση - Υλίκη	Reservoir	Υλίκη	200	1/10/2003	1/9/2013
2	Απορροή - Υλίκη	Reservoir	Υλίκη	200	1/10/2003	1/9/2013
3	rainfallMornos2000years.txt	Reservoir	Μόρνος	200	1/10/2003	1/9/2013
4	runoffMornos2000years.txt	Reservoir	Μόρνος	200	1/10/2003	1/9/2013
5	Βροχόπτωση - Εύηνος	Reservoir	Εύηνος	200	1/10/2003	1/9/2013
6	Απορροή - Εύηνος	Reservoir	Εύηνος	200	1/10/2003	1/9/2013
7	Βροχόπτωση - Μαραθώνας	Reservoir	Μαραθώνας	200	1/10/2003	1/9/2013
8	Απορροή - Μαραθώνας	Reservoir	Μαραθώνας	200	1/10/2003	1/9/2013

The time series data management form provides the user with the possibility

- to manage time series sections (**Series/Add sections..., Series/Insert sections..., Series/Delete sections...**) thus configuring hydrological scenarios.
- to load and write time series to a file (**Series/Load from file..., Series/Write to file...**).
- to import and delete records from the time series table (**Edit/Add records..., Edit/delete records...**).
- to copy field values to and from the clipboard (**Edit/Copy, Edit/Paste**).
- to show statistics (**View/Show section statistics**).
- to display the graphs of selected time series or time series sections (**Graphs**).
- to display statistical characteristics of the time series using the add-on software **Pythia** (**Tools/Pythia**).



	Section: 1	Section: 2	Section: 3	Section: 4	Section: 5	Section: 6	Section: 7	Section:
2003/10	10,58	7,11	17,12	16,43	10,98	25,66	12,66	3
2003/11	37,06	38,09	48,58	57,41	59,50	31,69	27,12	2
2003/12	3,57	52,00	28,32	59,86	56,81	118,14	62,65	0
2004/01	0,00	62,10	74,22	104,59	21,25	62,41	44,26	0
2004/02	0,00	40,08	63,96	85,30	94,16	70,02	52,04	0
2004/03	10,38	38,16	43,11	54,35	96,91	78,87	34,07	14
2004/04	15,68	40,68	54,42	49,53	66,23	53,61	47,63	23
2004/05	12,36	39,55	38,07	41,73	71,06	33,85	25,77	15
2004/06	4,85	12,45	14,86	20,23	26,17	17,88	9,19	14
2004/07	7,54	10,50	10,48	17,73	14,38	11,55	6,95	6
2004/08	12,76	5,02	4,82	16,17	18,86	6,15	9,72	10
2004/09	9,48	11,10	4,34	13,66	8,88	18,52	6,34	11
2004/10	25,32	40,38	28,67	18,45	0,66	17,68	1,12	16
2004/11	57,06	32,43	24,90	23,42	12,33	41,63	35,43	0
2004/12	30,24	59,18	11,20	102,55	52,44	260,23	92,57	0
2005/01	50,00	23,62	45,42	160,36	83,98	37,06	38,07	0
2005/02	0,00	20,08	47,41	127,17	77,17	48,85	50,16	0
2005/03	20,90	36,71	39,78	24,67	83,08	51,38	70,72	13

Note: Additional functions and information about time series management are provided by HYDROGNOMON Time Series Management System.

Part V

5 Simulation

5.1 General

During the simulation water is transported from the resources (reservoirs, boreholes, rivers, inflows) to the water users (water supply, irrigation, hydropower generation, environmental preservation etc.). Simulation is performed **step-by-step**, taking into account the typical quantities of the hydrosystem, the targets and the current operating rules. Upon simulation, HYDRONOMEAS calculates the **optimum allocation** of water resources at each time step, aiming at:

- strictly complying with the physical restrictions of the network (reservoir capacities, aqueduct and pump station discharge capacities, etc.).
- minimizing the spills of reservoirs (spills take place only if the discharge capacity of the downstream network has been exhausted).
- achieving the targets, in accordance with the hierarchy set by the user.
- minimizing the deviation from desirable quantities provided by the operating rules (e.g. reservoir storage targets).
- achieving the best financial performance (minimize the water transport cost, minimize the pumping cost, maximize the benefit from hydroelectric power generation).

Note:

HYDRONOMEAS incorporates an **abstraction allocation model**, which transforms the components of the hydrosystem into components of a virtual graph, where it imports virtual values of discharge capacity and cost. It is therefore demonstrated that simulation is a step-by-step resolution of a series of linear programming problems. The computational procedure is fully automated and does not require any intervention by the user.

5.2 Operating Rules

The operating rules are generalized rules that apply to specific components of the network, setting a specific policy for their management. More particularly, according to operating rules the desirable withdrawals:

- from ground waters (reservoir operating rules) and
- from aquifers (borehole operating rules)

are calculated at each time step, in conjunction with the total available storage and the total demand.

The mathematical description of operating rules is made through a specific number of parameters that remain constant throughout the simulation period. Therefore, after the end of the simulation, it is possible to evaluate the specific **administrative policy** , as described by the parameters of the operating rules, against different performance measures, such as reliability, cost, etc. By changing the values of parameters, different operating rules are applied, and thus the simulation produces different results.

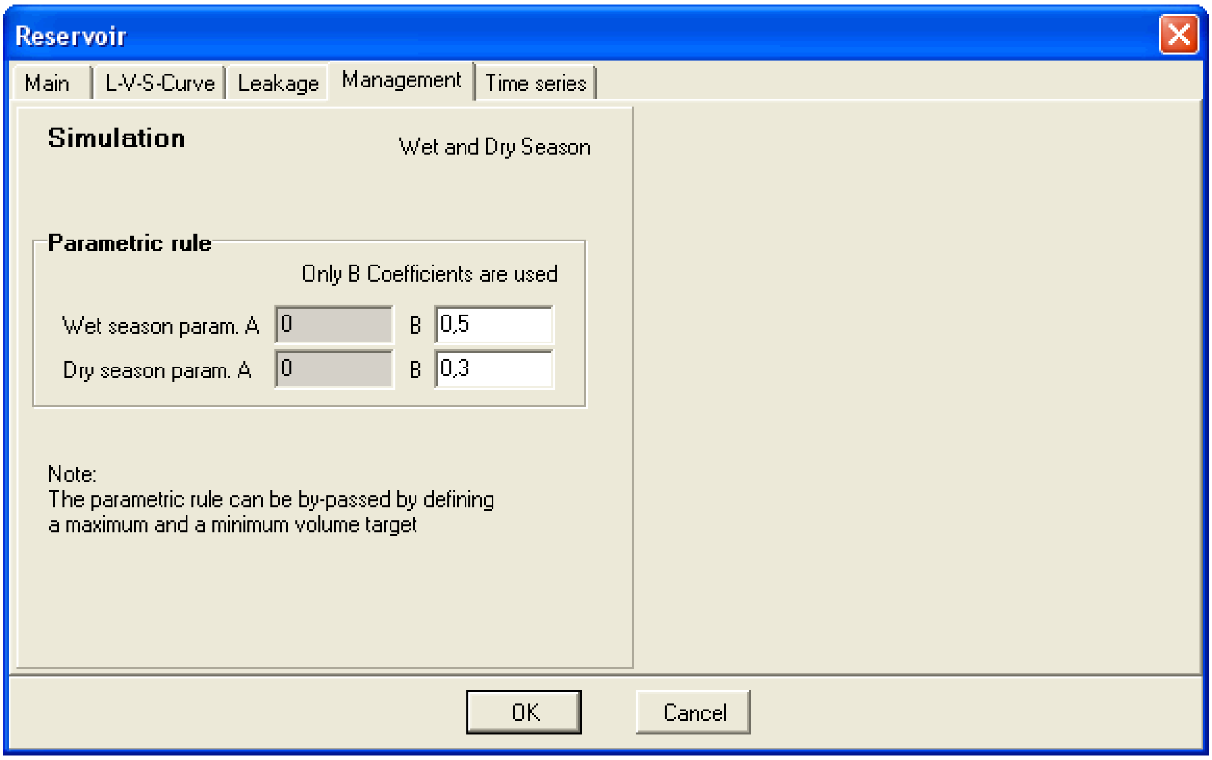
Note: In a simple simulation, the parameters of operating rules are provided by the user. The optimization process permits the automatic calculation of these parameters.

5.2.1 Reservoir operating rules

Reservoir operating rules evaluate the desirable allocation of their storage, in conjunction with the total useful storage that is expected to be available at the end of the time step. The evaluation of desirable storage depends on the following factors:

- the total storage of reservoirs at the beginning of a time step.
- expected hydrological inflows of each reservoir due to catchment runoff or rainfall, after deducting the expected losses due to evaporation and leakages.
- the total water demand to meet consumption targets.
- the useful capacity of each reservoir and the total useful capacity of the system.
- the desirable variation of each reservoir's storage, based on the current values of minimum and maximum volume targets (is set).

In the 4th sheet of the reservoir data form, the user can set the operating rule of a reservoir, by setting one or two seasonal parameters (a, b) in the **Parametric Rule** area. The operating rules may remain the same in every month of the year or change during the dry and wet period. The number of parameters used is given in the options form. The parameter values may vary between 0 and 1.



At each time step, based on the current desirable storage, the respective **desirable water withdrawal** from each reservoir is calculated. The simulation model seeks to meet the specific withdrawal, provided this does not oppose to the physical restrictions of the network (e.g. the specific withdrawal cannot be conveyed downstream due to exhaustion of the discharge capacity of downstream aqueducts) and the operating targets of the hydrosystem (e.g. a greater withdrawal is required to meet a downstream demand). Otherwise, the model calculates a water outflow that is as close as possible to the desirable one.

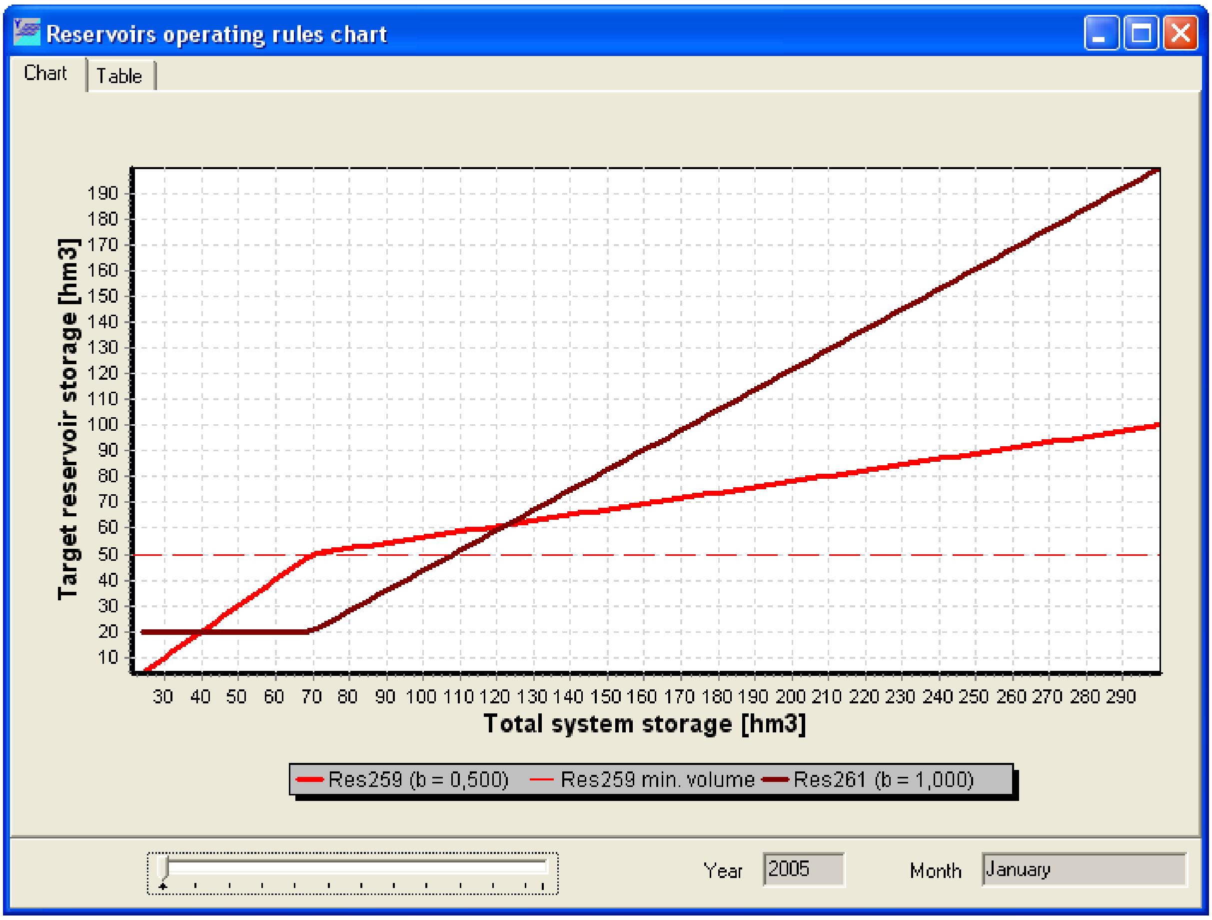
Notes:

In a relatively complex hydrosystem, with a complicated topology and opposing targets, the **actual withdrawals** usually differ from the desirable ones. This means that the management of a hydrosystem mainly depends on the different restrictions set (due to the physical characteristics of the system and due to the user defined targets) and secondarily on the operating rules.

More information on the parametric rule for the operation of reservoirs is provided by Nalbantis and Koutsoyiannis, 1997.

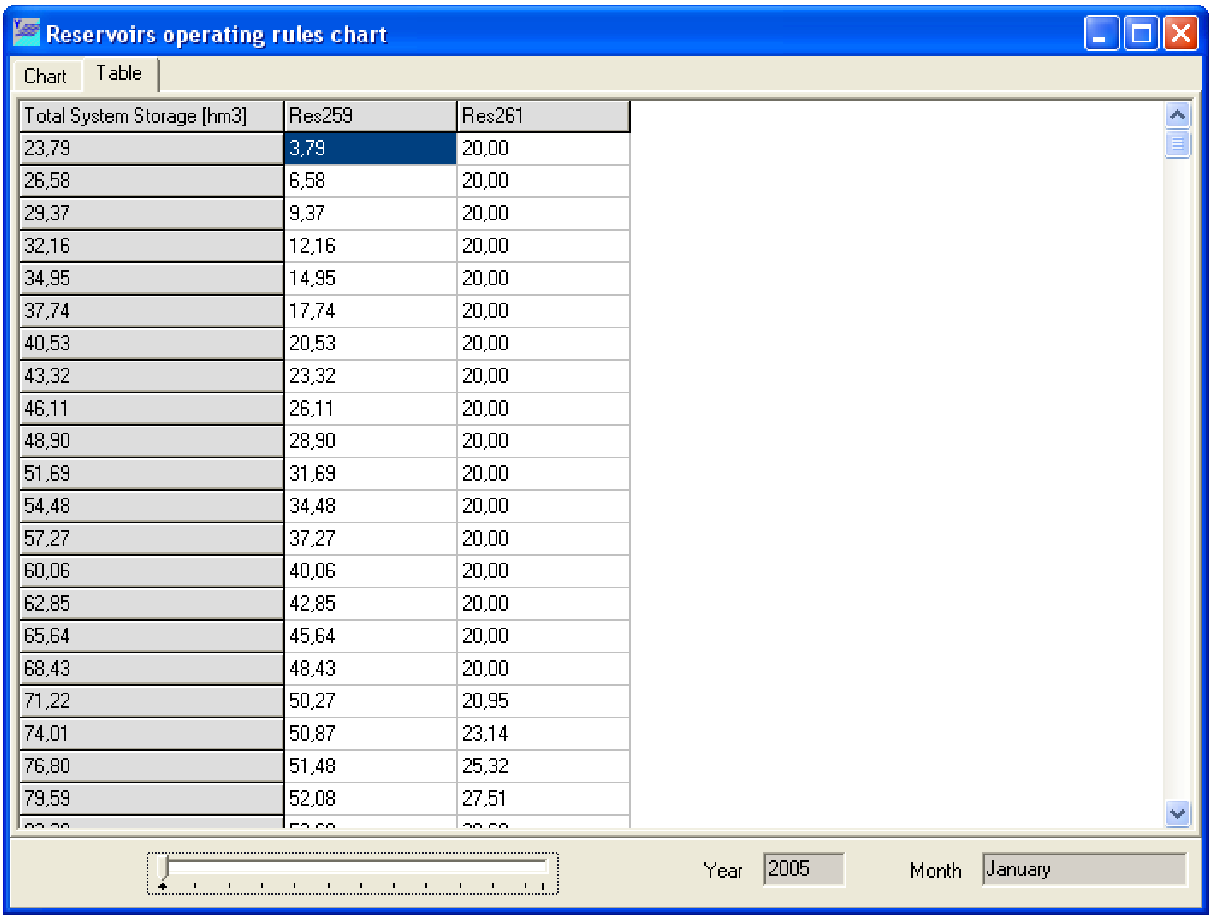
5.2.2 Graphical representation of reservoir operating rules

Reservoir operating rules of the current scenario can be represented in the form of a graph by selecting from the menu of the Main Form **Tools/Show reservoir rules**.



The form displayed shows the graph of reservoir current operating rules. The graph sets the desirable storage of each reservoir (target storage) in relation to the total system storage. Below the graph, are listed the current a and b coefficients of reservoirs. From the scroll bar, you can select the time step that applies to the graph.

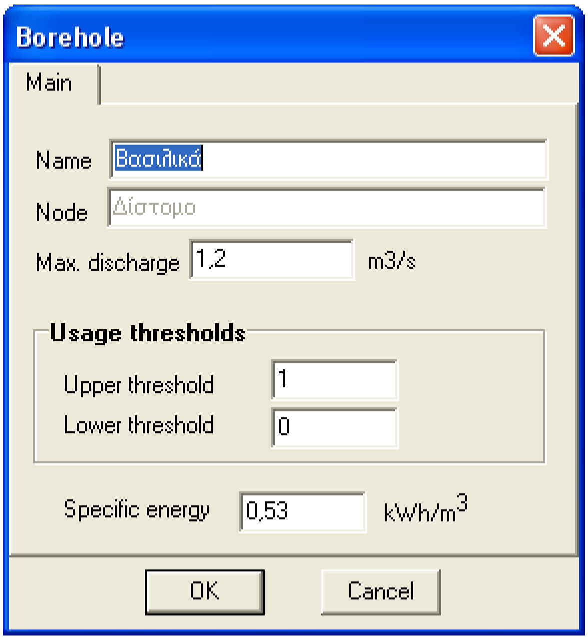
The second sheet of the form **(Table)** lists the operating rule of reservoirs in the form of a table that matches the desirable reservoir storage to the total system storage.



Total System Storage [hm3]	Res259	Res261
23,79	3,79	20,00
26,58	6,58	20,00
29,37	9,37	20,00
32,16	12,16	20,00
34,95	14,95	20,00
37,74	17,74	20,00
40,53	20,53	20,00
43,32	23,32	20,00
46,11	26,11	20,00
48,90	28,90	20,00
51,69	31,69	20,00
54,48	34,48	20,00
57,27	37,27	20,00
60,06	40,06	20,00
62,85	42,85	20,00
65,64	45,64	20,00
68,43	48,43	20,00
71,22	50,27	20,95
74,01	50,87	23,14
76,80	51,48	25,32
79,59	52,08	27,51

5.2.3 Borehole operating rules

The operating rules of boreholes use two threshold parameters for each borehole, the upper threshold (bup) and the lower threshold (bdown), that permit or not underground withdrawals, depending on the total system storage.



More specifically, the operation of each borehole is based on the following rule:

- when the total reservoir storage at the beginning of a time step is greater than the percentage of bup **(Upper threshold)** on the total useful capacity of reservoirs (i.e. total abstractable potential of the system), then the operation of the borehole is not permitted.
- when the total reservoirs storage at the beginning of a time step is lower than the percentage of bdown **(Lower threshold)** on the total useful capacity of reservoirs, then it is required to activate a borehole, regardless of cost, due to the energy consumption.
- in all other cases, the use of a borehole is controlled by the abstractions allocation model, based on its actual financial quantities.

Both threshold parameters of each borehole are given in the borehole data form and obtain values within the range of [0, 1], with the lower threshold obviously always being lower than the upper threshold.

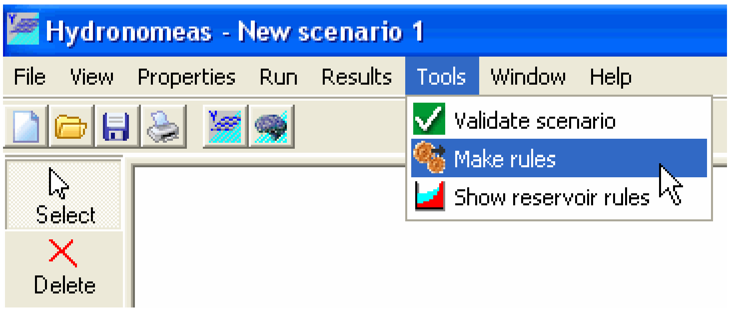
5.2.4 Management of operating rules

During a session, the user can perform a series of simulations using different operating rules of his choice.

A way of entering operating rules is using the relevant data forms, i.e. the reservoir data form for reservoirs and the borehole data form for boreholes. The operating rules entered in this way are called **current operating rules** of the scenario and are those that will apply if the simulation is performed.

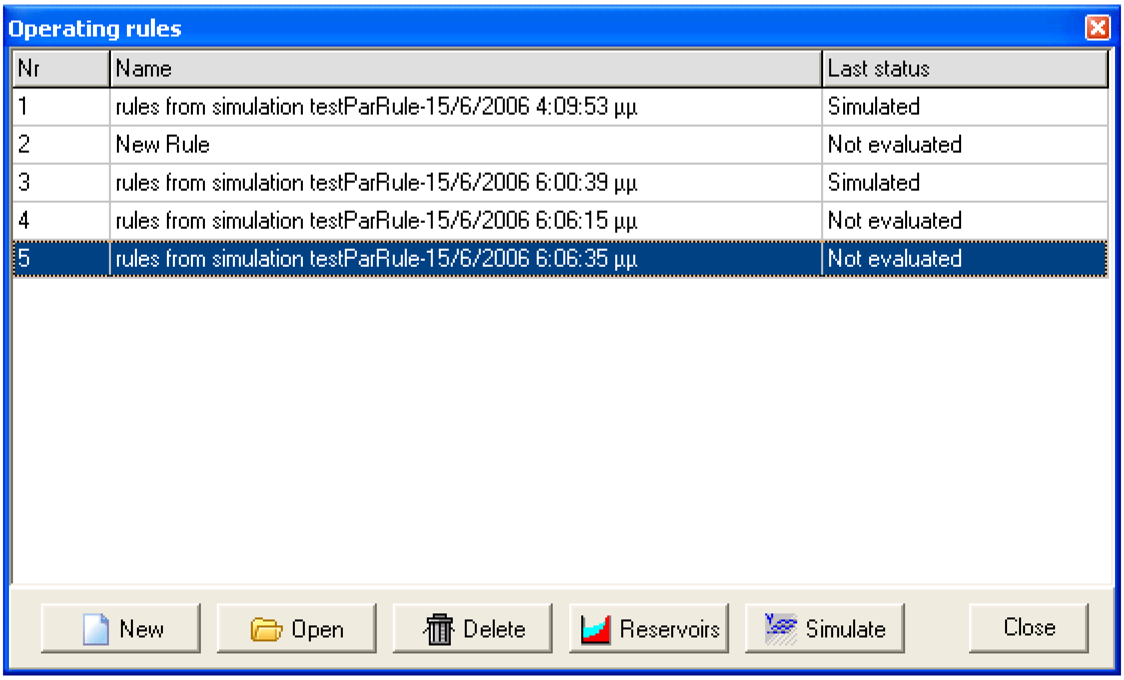
The current operating rules can be saved and used later in one of the following ways:

- Select **Tools/Make rules** from HYDRONOMEAS Main Form menu.



➲ By launching the simulation, the current operating rules are automatically saved.

Management of operating rules is made from the table of operating rules that appears by selecting **Properties/Rules** from the Main Form.



The table displayed includes all saved operating rules of the scenario. Each line of the table refers to a set of operating rules for all reservoirs and boreholes of the network, whereas columns provide the name of the rules **(Name)** and their last status **(Last status)**, which can be either **Simulated** when a simulation has been performed or **Not evaluated**.

The form provides the following management operations:

➲ **New**: Opens the form to create new operating rules.

➲ **Open**: Opens the form to preview and modify the selected operating rules.

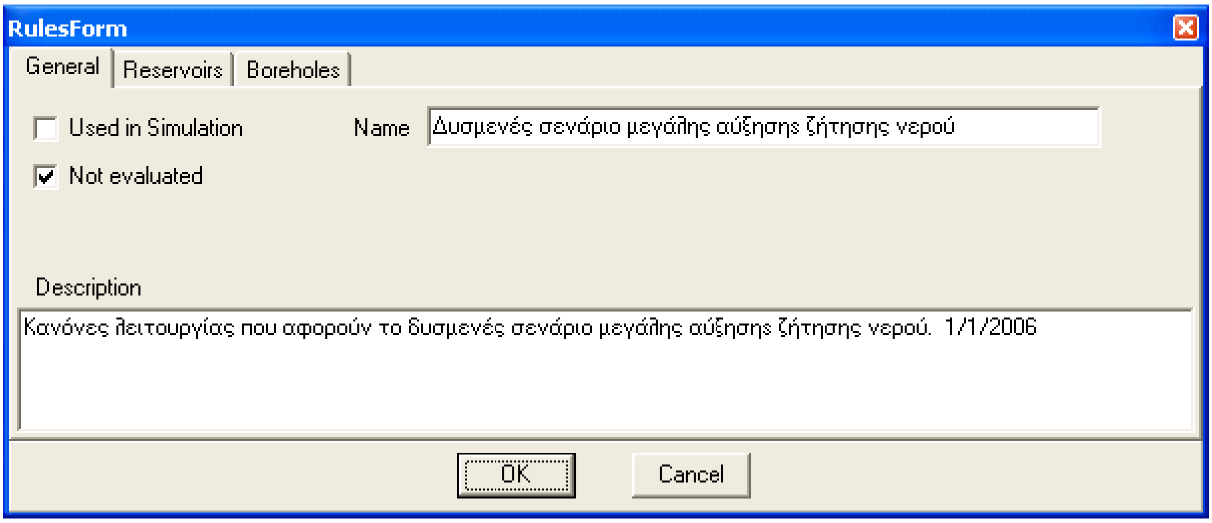
➲ **Delete**: Deletes the selected operating rules.

➲ **Reservoirs**: Shows the graphical representation of reservoir operating rules.

➲ **Simulate**: The simulation is performed with the selected operating rules.

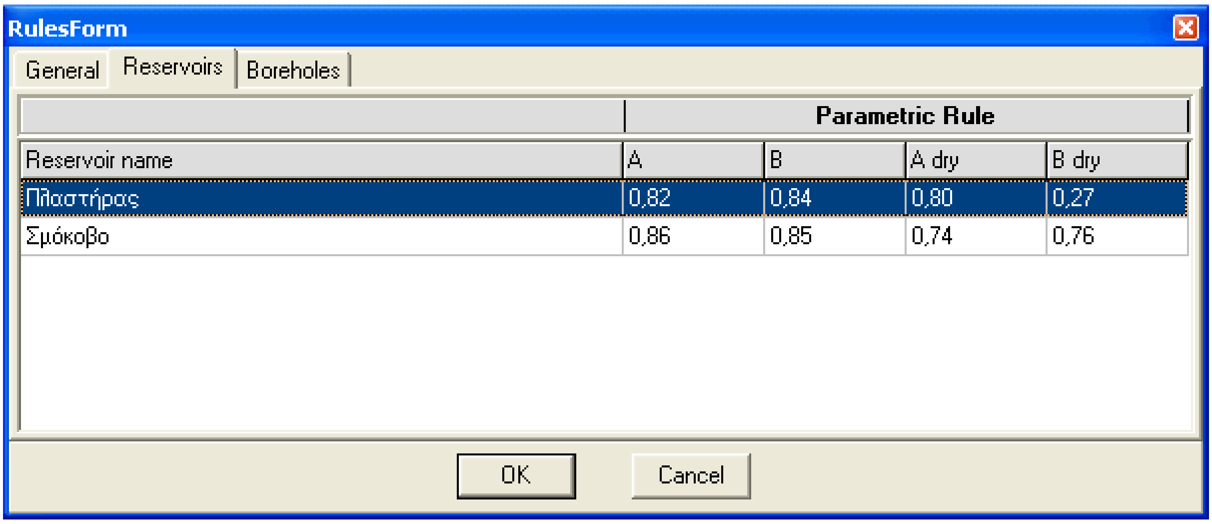
By selecting New or Open, the operating rules form opens which is divided in three sheets:

The main sheet **(General)** includes fields to enter or modify the name of operating rules **(Name)** and their description **(Description)**.

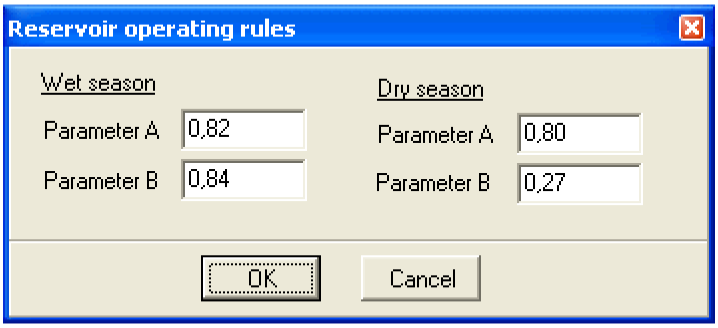


Furthermore, there are marks that show whether the operating rules have been used in a simulation **(Used in Simulation)** or not **(Not evaluated)**. These marks cannot be changed by the user.

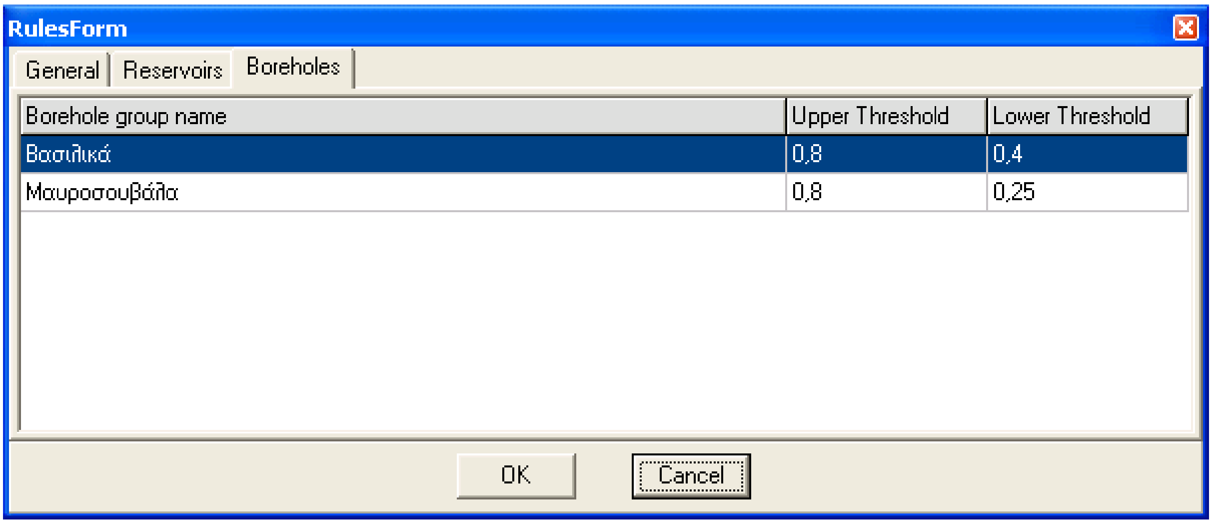
The next sheet concerns the reservoir operating rules and lists in table format the **A** and **B** parameters of the operating parametric rule **(Parametric rule)**. If you have selected seasonal differentiation of operating rules, then values are set in the columns that apply to the dry period and are marked **dry.**



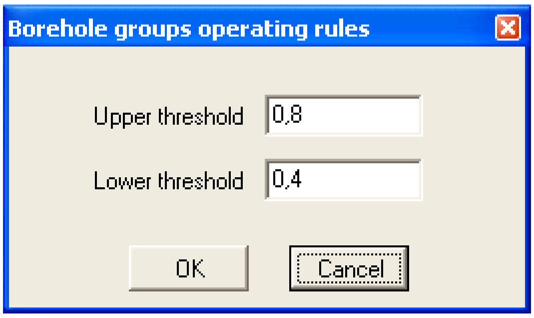
In case where the operating rules have not yet been used in a simulation, double-click on a line of the reservoir table, to show the reservoir's operating rule import form and change all the options.



The last sheet refers to borehole or borehole group operating rules and lists in table format the **Upper Threshold** and **Lower Threshold** of use.

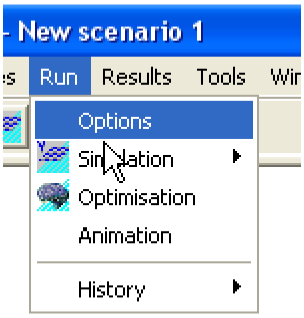


In case where the operating rules have not yet been used in a simulation, double-click on a line of the borehole table, to show the borehole's operating rule import form and change the values of thresholds.



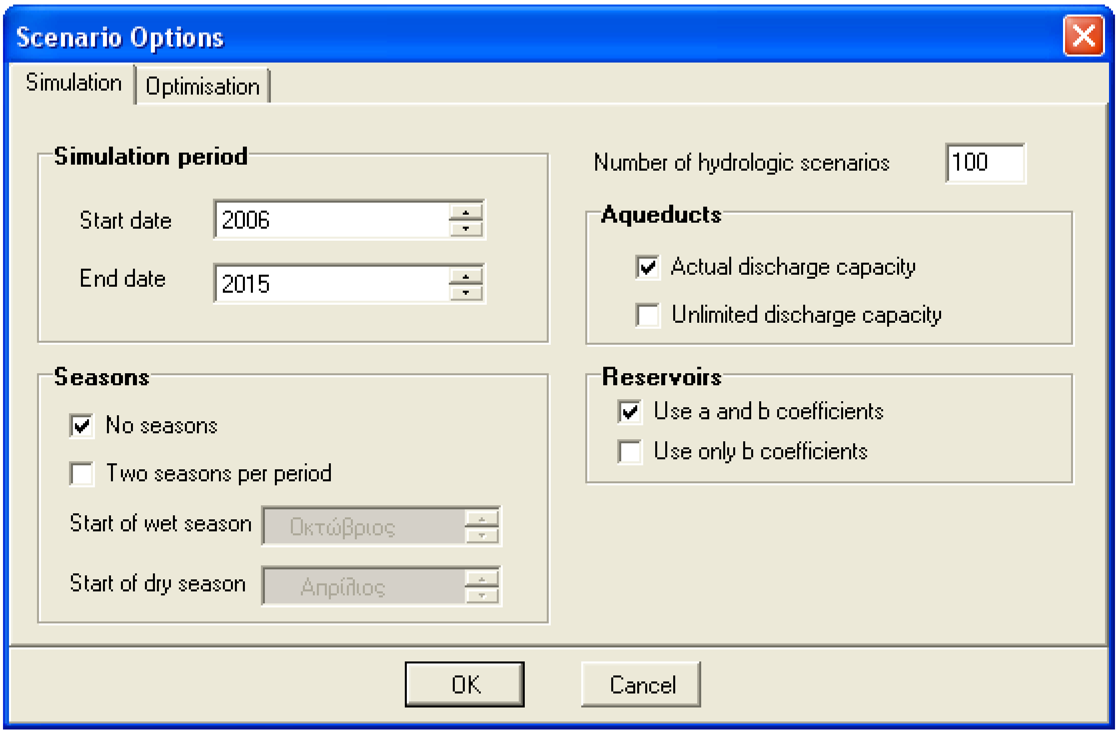
5.3 Options

A scenario's options are set in the options form that appears on the screen by selecting **Run/Options** from the menu of HYDRONOMEAS Main Form.



In the **Simulation** sheet, the user can set the following principal simulation operations:

- In the Hydrologic scenarios area, set the number of hydrologic scenarios **(Number of hydrologic scenarios)** to be simulated and the initial and final simulation year **(Start date, End date)**. Integral calendar years are always simulated, i.e. the initial month is always January and the final month is always December.
- In the **Aqueducts** area, the user sets whether the simulations shall be performed with the actual discharge capacity values **(Actual discharge capacity)** provided in the reservoir data form or using the unlimited discharge capacity option **(Unlimited discharge capacity)**. The latter option is useful when calculating the theoretical potential of a hydrosystem, regardless of the discharge capacity constraint of aqueducts.
- **Seasons** area concerns the seasonal differentiation of reservoir operating rules: By selecting **No seasons** the user selects to use constant operating rules throughout the year. On the contrary, by selecting **Two seasons per period,** operating rules are seasonally differentiated, and the start of wet and dry season is in the months set in **Start of wet season** and **Start of dry season** fields, respectively.
- In **Reservoirs** area, the user sets whether the parametric rules for the operation of reservoirs are set by two coefficients or not **(Use a and b coefficients)** or by only one coefficient **(Use only b coefficients)**.

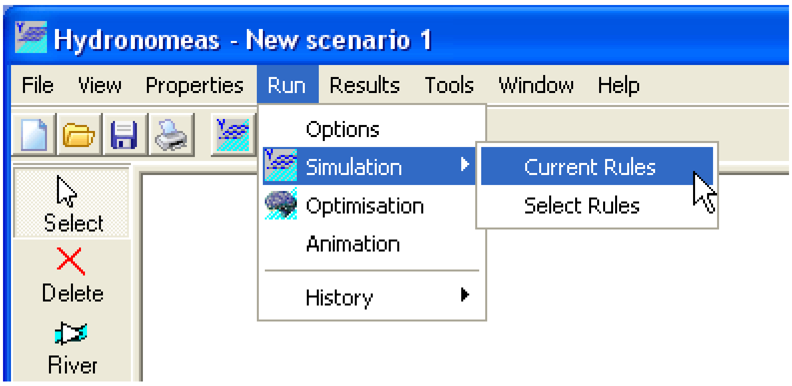


Note: More information on the parametric rule for the operation of reservoirs is provided by Nalbantis and Koutsoyiannis, 1997.

5.4 Performing a simulation

A simulation is performed with the current operating rules using one of the following ways:

➲ Select **Run/Simulation/Current Rules** from the Main Form menu.



➲ By clicking the **Simulation** icon () from the basic operations icons of the Main Form.

Following the performance of data validation and provided no errors are found, the simulation is performed in the background. The screen displays the simulation monitoring form where the user can verify the progress and check the process.

Notes:

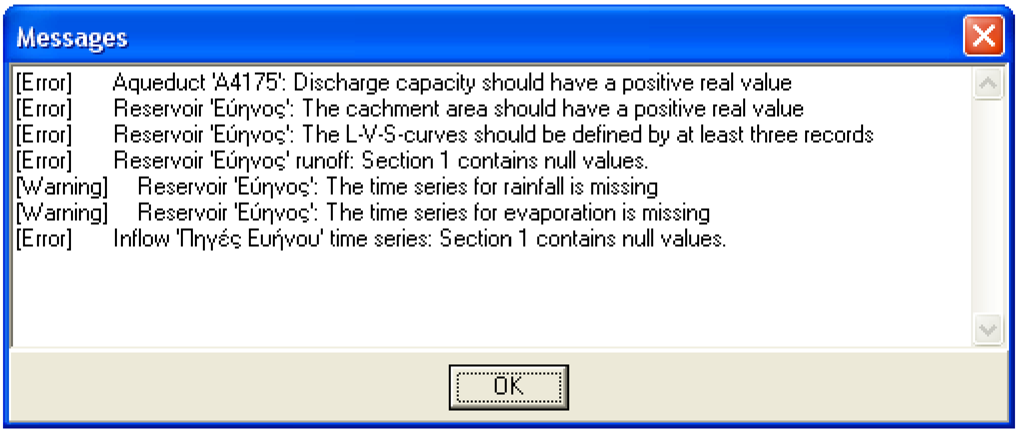
➲ During the simulation the user can visualize the procedure by selecting from the Main Form the **Animation** bookmark.

- By selecting **Run/Simulation/Selected Rules** from the main menu form, the saved operating rules form appears, where the user can select and execute another operating rule.

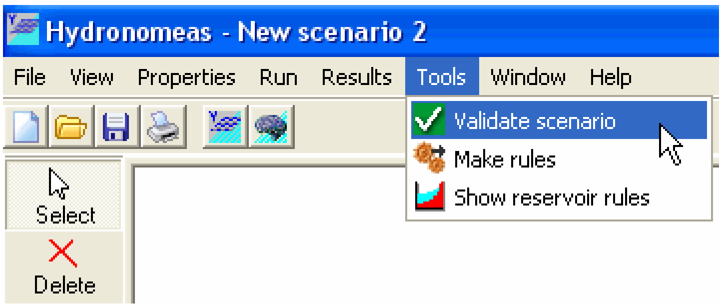
5.4.1 Data validation

Before launching the simulation, HYDRONOMEAS performs a validation of scenario's data. In case where data will result from this validation, these are detailed in a list. All pieces of information are classified in one of the following categories:

1. **Error**
   In case of error, it is impossible to perform the simulation. The user has to correct all the errors in order to perform the simulation. By clicking the **OK** button, the control of the system returns to the user.
2. **Warning**
   This is an important information that might affect the progress of the simulation, but it does not prevent its performance. The user can ignore the warning and if no faults have been identified, the user can perform the simulation, by clicking **OK**.
3. **Information**
   This is a simple notification that has no impact on the progress of the simulation.



Note: Validation can also be performed regardless of performing the simulation, by selecting **Tools/Validate scenario** from HYDRONOMEAS Main Form menu.



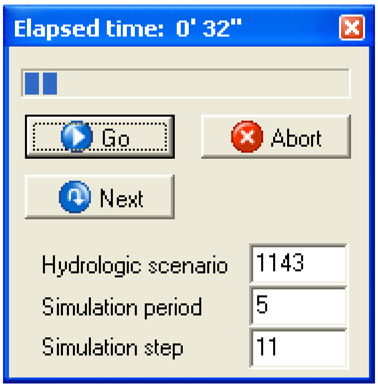
5.4.2 Monitoring of the procedure

During the visualization of the simulation the following simulation monitoring form appears:

The user can monitor the simulation procedure, by clicking the following buttons:

- **Hold:** The simulation is temporarily interrupted.
- **Abort**: The procedure is cancelled: No results are saved.

In case where you click the **Hold** button, this is renamed **Go** and the form turns as follows:



- **Go**: The simulation is resumed from the point it was interrupted. The forms turns into its first version.
- **Next**: Jump to the next time step.

Moreover, the current time step of the simulation is given in three fields.

- **Hydrologic scenario**: The current hydrologic scenario.
- **Simulation period**: The current period (simulated year).
- **Simulation step**: The current step (simulated month of the year).

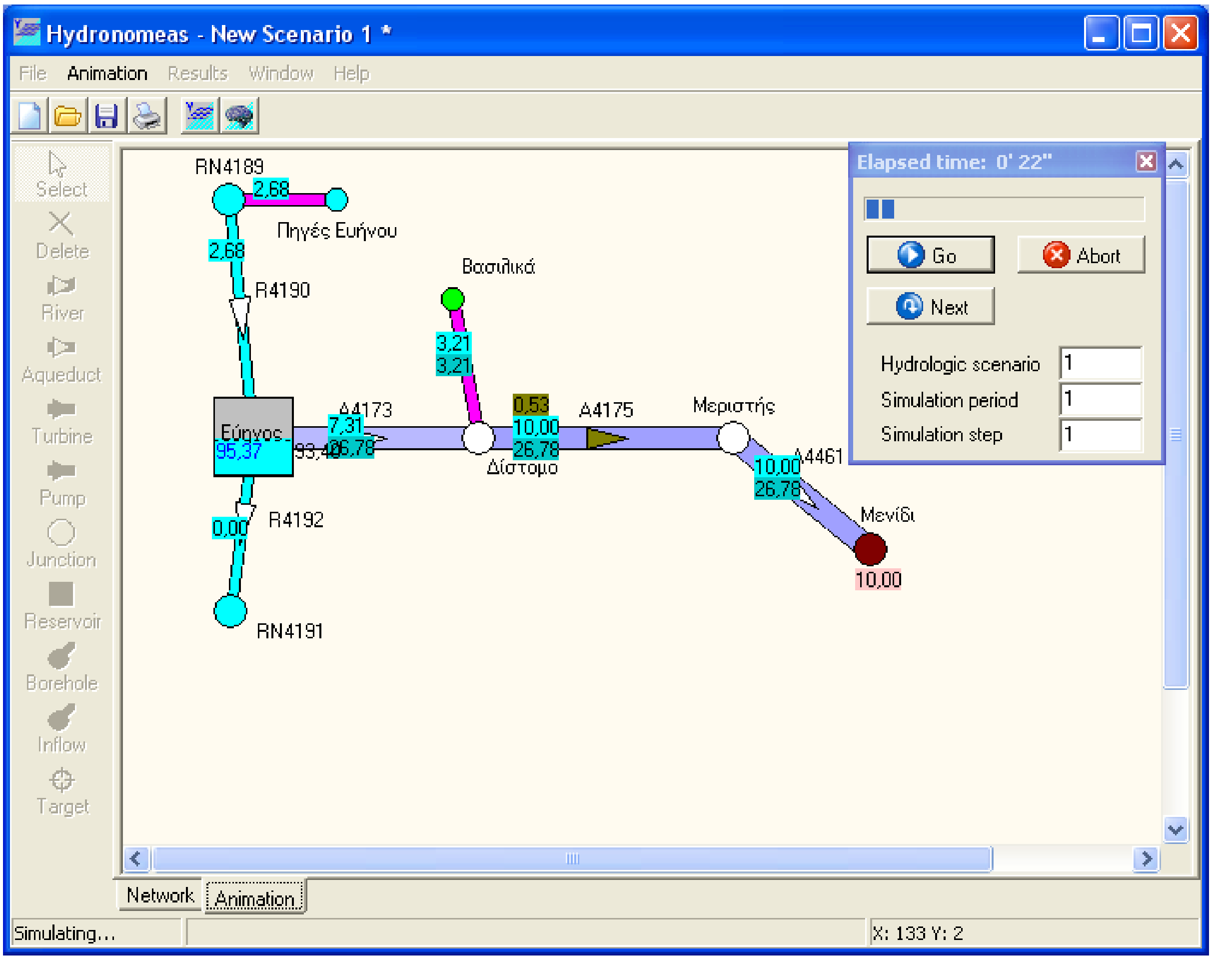
Part VI

6 Simulation visualization

The simulation procedure can be visualized both in real time and in retrospection. The user can preview the status of the network in each step of the simulation. More particularly, the user can monitor:

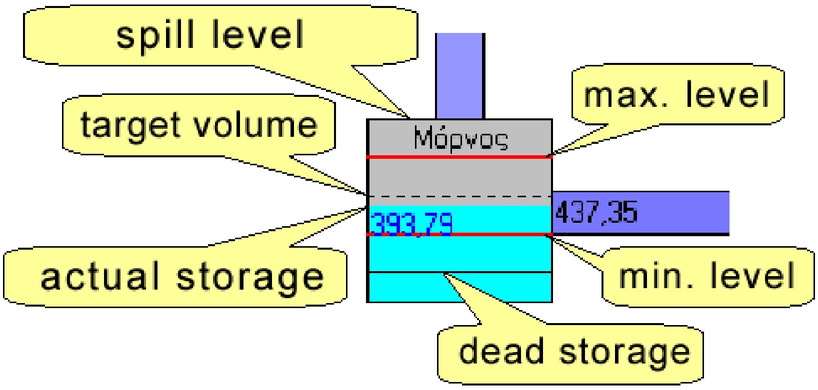
- The choices made through HYDRONOMEAS concerning water transport, in order to meet the operating targets set by the user and to meet the objectives and constraints of the system.
- The quantities carried through the hydrosystem's conduits (aqueducts, rivers, pumps, turbines) in relation to their discharge capacity.
- The actual reservoir storage as to the desirable variation, the target volume, the dead volume and the spill volume.
- The quantities of water used in the hydrosystem's model from aquifers and external resources (inflows).
- The failure to meet operating targets set by the user.

The simulation procedure is visualized in the simulation visualization sheet displayed by clicking on the **Animation** bookmark in Hydronomeas Main Form. This sheet shows the network's diagram with the same layout as in the network design form.

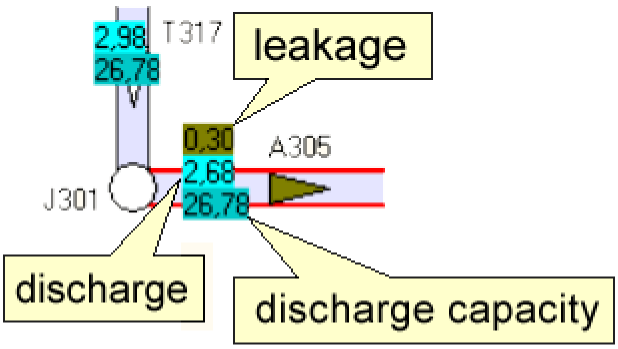


Note: The simulation visualization sheet is only displayed during the simulation or if a simulation has been performed without having changed scenario's data. Otherwise, the simulation has to be repeated.

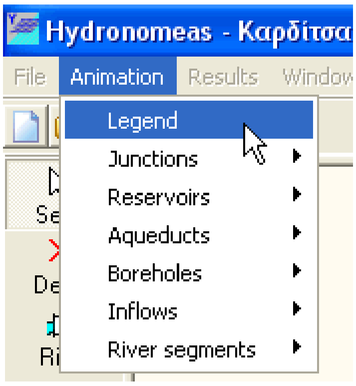
The reservoir storage is displayed in blue. The level that corresponds to the target volume of the operating parametric rule is represented with a horizontal dashed line, and the dead volume with a solid black line. The upper and lower thresholds of volumes that the user may have set (see simulation targets) are represented with a solid red line.



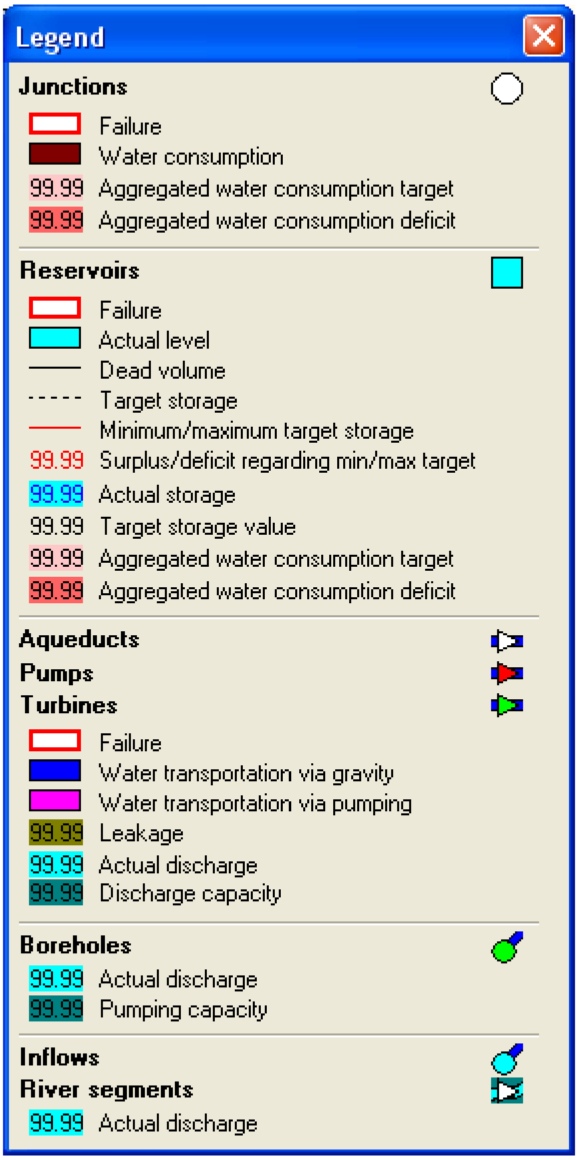
The blue gradient of conduits shows the volume of water carried from them as to their discharge capacity. Flows resulting from pumping are represented as pink hues.



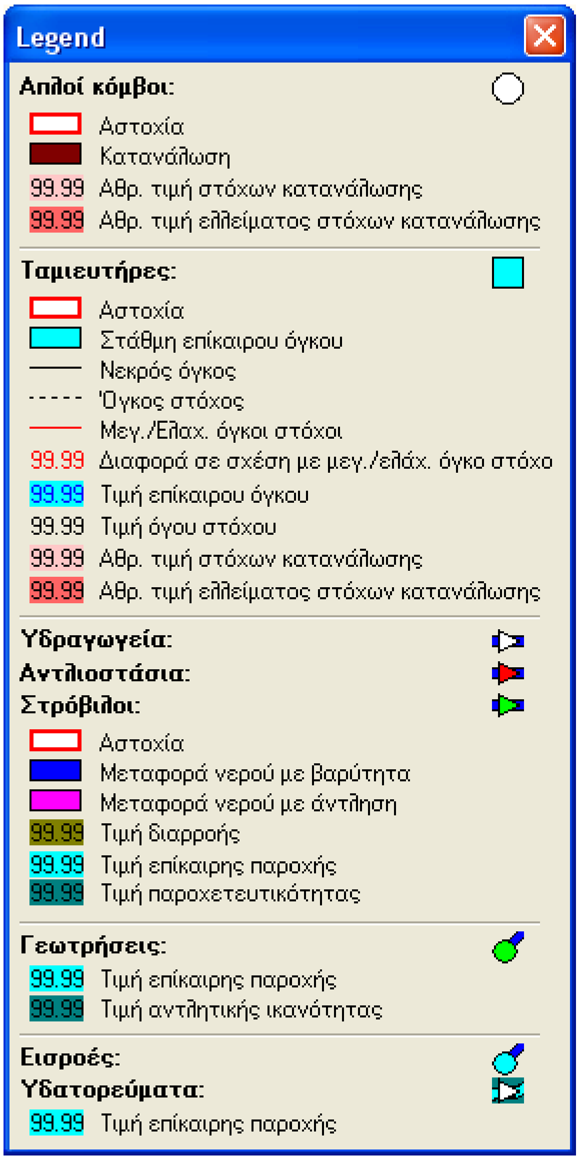
The legend of the simulation visualization sheet is displayed by selecting **Animation/ Legend** from the menu of the Main Form.



and informs the user about all labels shown:



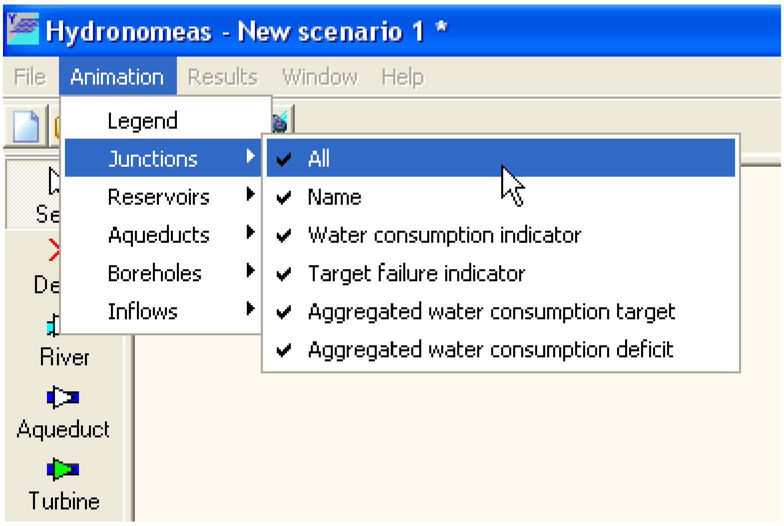
The legend of the simulation visualization sheet



The translation of the legend in Greek

Notes:

- The visualization of the network, together with the simulation, considerably increases the processing load of the computer and retards the simulation procedure.
- By selecting **Animation/...** from the menu of the Main Form, the user can show/hide the selected label groups.



- At any time during a simulation, the user can visualize the simulation procedure, by selecting the **Animation** sheet or let the procedure continue without visualization, by selecting the **Network** sheet.

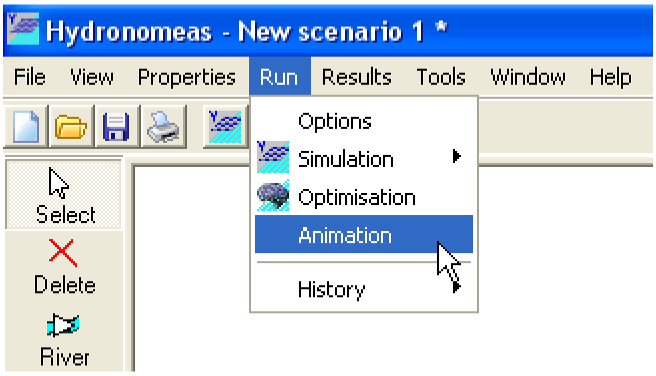
Information about monitoring the visualization procedure is available in chapters:

- Visualization during the performance of a simulation.
- Recursive visualization of a simulation.

6.1 Visualization during the performance of a simulation

The procedure of simulation can be visualized, as from the very first time step (month), as follows:

1. Select **Run/Animation** from HYDRONOMEAS Main Form menu.



2. If scenario data are valid the visualization sheet (**Animation**) appears in the status following the performance of the first time step (1st month) of the first

hydrological scenario.

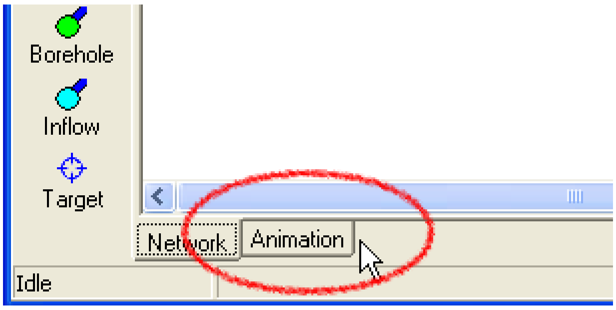
3. The simulation is temporarily interrupted and the user can perform any action by selecting the appropriate options from the simulation monitoring form.

Notes:

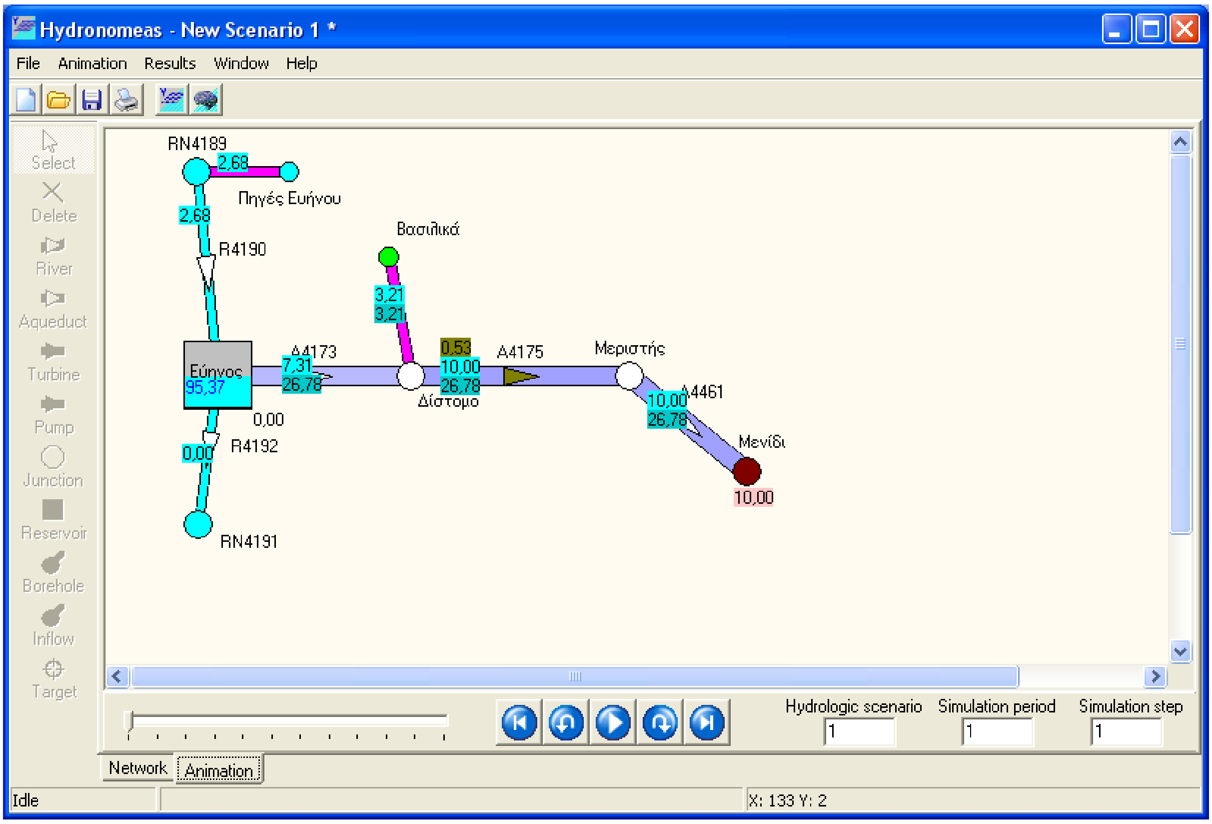
- The user can at any time visualize the simulation procedure by selecting from the Main Form the **Animation** bookmark. When selecting the **Network** bookmark, the simulation is performed in the background.
- The visualization of the network, together with the simulation, considerably increases the processing load of the computer and retards the simulation procedure.

6.2 Recursive visualization of a simulation

After terminating a simulation, you can recursively review step-by-step the simulation. The simulation visualization sheet remains available and is displayed on the screen if selected by clicking on the **Animation** bookmark in Hydronomeas Main Form.



The simulation visualization sheet appears.



On the lower part of the picture, the following visualization monitoring tools are displayed:

- The **scroll bar**, with which the user can drag and visualize any time step of the last simulation.
- The time step shown includes three fields:
  1. **Hydrologic scenario**: The current hydrologic scenario.
  2. **Simulation period**: The current period (simulated year).
  3. **Simulation step**: The current step (simulated month of the year).
- The navigation buttons:

Previous hydr. scenario: Jump to the beginning of the previous hydrological scenario.

Previous step: Jump to the previous time step (month).

Go: Resume simulation from the point it was interrupted.

Hold: During the simulation, the **Go** button is renamed **Hold** and if clicked, the simulation is interrupted.

Next step: Jump to the next time step (month).

Next hydr. scenario: Jump to the beginning of the next hydrological scenario.

<u>Note:</u> The recursive simulation visualization is only possible if the simulation has been performed without having changed scenario's data. Otherwise, the simulation has to be repeated.

Part VII

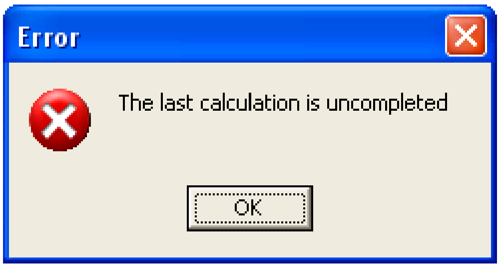
7 Simulation results

The results of calculations are available after having fully performed the simulation and are divided in the following categories:

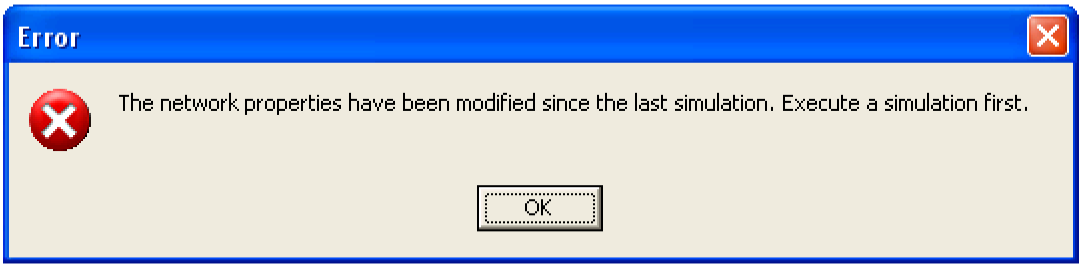
- Failure forecast for targets set and their time distribution.
- Water and energy balances: In addition to the monthly average, the standard deviation for the selected time period is calculated.
- Forecast of reservoir storage: In case where the scenario includes a simulation with multiple hydrological scenarios, the results are provided in the base of storage forecast equiprobable curves.

Notes:

The results of calculations always concern the last calculation and are available only if the simulation procedure has been completed. In case of early interruption of the procedure, the user must resume and complete the simulation, for which the user is prompted through a relevant message:



Any change to the data of the current scenario, e.g. modification of the network, the targets or simulation settings makes impossible the preview of the results of the previous simulation, as they do no longer correspond to the current scenario. A relevant message appears on screen and the simulation has to be resumed.



7.1 Failure forecast for targets and constraints

One of the main features of Hydronomeas is that it calculates all hydrological quantities in probability terms. More particularly, in what concerns the targets and constraints of the hydrosystem, the application calculates different failure measures which are aggregated in the system's failure form that is shown by selecting **Results/ Failure probability** from the menu of the Main Form.

Target failure probability

Target	Mean annual failure	Max. annual failure	Failed time steps	Mean annual deficit	Max. annual deficit
1) Μαραθώνας - No spill	0.000	0.000	0	0.000	-
2) Μαραθώνας - Min. volume	0.008	0.010	6	0.145	-
3) Ποταμός Εύηνος - Const. flow	0.125	0.205	106	2.702	-
4) Εύηνος - Max. volume	0.203	0.260	195	9.529	-
5) Ενωτικό Διστόμου - Max. flow	0.008	0.010	8	0.026	-
6) Αθήνα - Water supply	0.008	0.010	6	0.090	0.134
7) Μαραθώνας - Max. volume	0.105	0.210	152	2.619	-
8) Κωπαΐδα - Irrigation	0.005	0.010	3	0.054	0.108

The term **failure** means non-fulfillment of the requested quantity at a specific time step. During the simulation, the model counts the time steps in which each target's requested value was not achieved and calculates the respective deficit (in the case of consumption and energy production targets and constraints of minimum reservoir storage and minimum aqueduct or river discharge) or excess (in the case of maximum reservoir storage and maximum aqueduct or river discharge).

The form lists a series of failure measures in table format, as follows:

1st column (Target): The name of the target/constraint.

2d column (Mean annual failure): Represents the mean annual failure, i.e. the rate of time periods (years) during which the desirable value of the target is not fully achieved, as to the total of simulated periods, i.e. the total length of the simulation in years.

3d column (Max. annual failure): Represents the maximum annual failure probability, by comparing for each simulated year the respective rate of hydrological scenarios in which desirable value of the target is not fully achieved. This probability is by default higher than or equal to the respective mean annual failure probability. The mean annual failure ratio is useful only if several hydrological scenarios are simulated (terminating simulation).

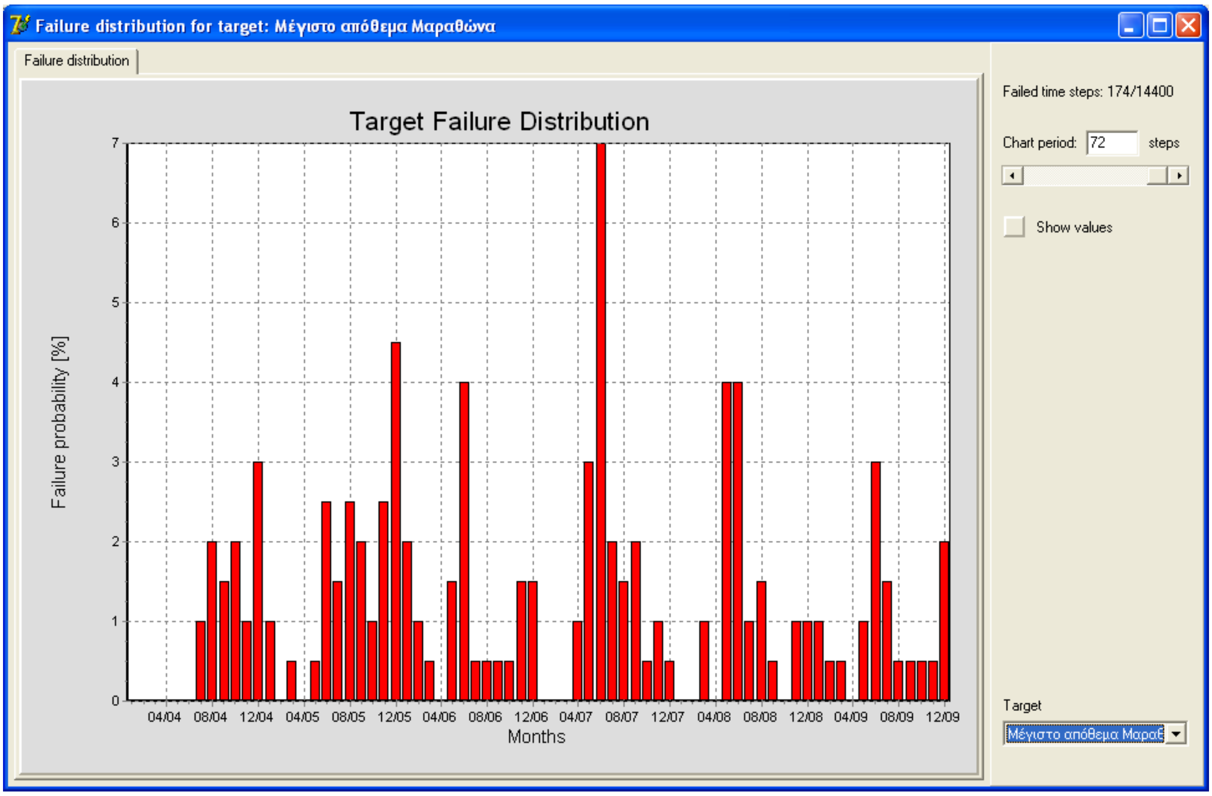
4th column (Failed time steps): Represents the number of failed time steps, i.e. the number of months during which the desirable value of the target is not fully achieved.

5th column (Mean annual deficit): Represents the mean annual deficit, i.e. the mean deviation from the annual target value throughout the term of the simulation.

6th column (Max. annual deficit): Represents the maximum annual deficit, by comparing for each simulated year the mean deviation from the respective annual target value for all hydrological scenarios.

7.2 Time distribution of failure probability

Unlike the total failure form, forecasting the time distribution of failure probability provides the user with the possibility to identify the timeframe of a possible deficiency of the system. The target failure probability forecast form is called from HYDRONOMEAS Main Form menu by selecting **Results/Failure Curves**.
The form gives in the form of graph the failure probability forecast for each month of the simulation period and each target set by the user.The failure probability is empirically calculated as the percentage of hydrological scenarios for which the requested target value has not been obtained. At the lower right part of the form, the user selects a target from the drop-down menu **(Target)**, and through the scroll bar, the user can limit the time period of the chart **(Chart period)**.



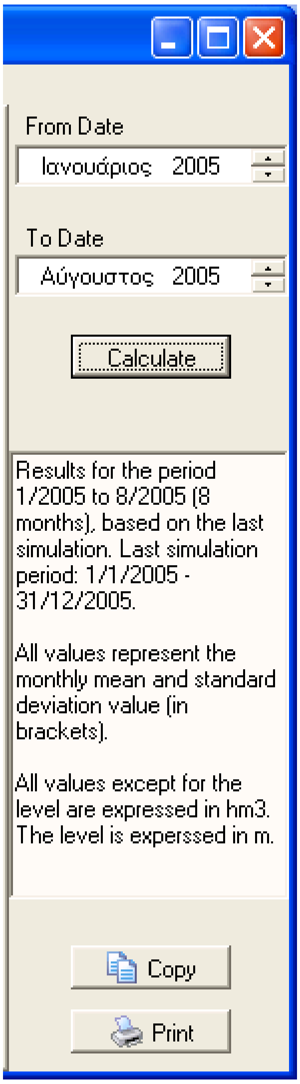
7.3 Balances

The form of balances is divided in four sheets and in the relevant four balance tables:

- The reservoir water balance **(Reservoirs)** summarizes all the inflows and outflows of reservoirs.
- The node water balance **(Nodes)** summarizes all the inflows and outflows of aqueduct and river nodes.
- The aqueduct and river water balance **(Conduits)**.
- The energy balance **(Energy)** refers to energy consumption and production when water is carried from the springs to the water use areas.

The balance form appears on screen after performing a complete simulation, by selecting **Results/Balance** from the menu of the Main Form. Balances refer to the averages of time steps (months) during the simulation with the most recent operating rule.

For all balance results, on the right part of the form, the balance results monitoring tools are displayed:



With the first two options **(From Date, To Date),** the user can set the timeframe to which the results of balances refer. To calculate/update a balance, the user must click **Calculate**. To the extent that, during simulation, multiple hydrological scenarios with long synthetic time series have been used, calculation of the new values of the balance might take a few more seconds.

The **Information** field includes information about balance data, such as the timeframe of results shown in the balance table and measuring units for relevant figures.

Clicking the **Copy** button you can copy the table to the clipboard in order to use the data in another Windows-based application, such as Microsoft Excel.

By clicking the **Print** button, you can send the form to a printer.

Finally, by double clicking with the mouse on a single value of the balance sheet, a time series form is shown.

7.3.1 Reservoir balance

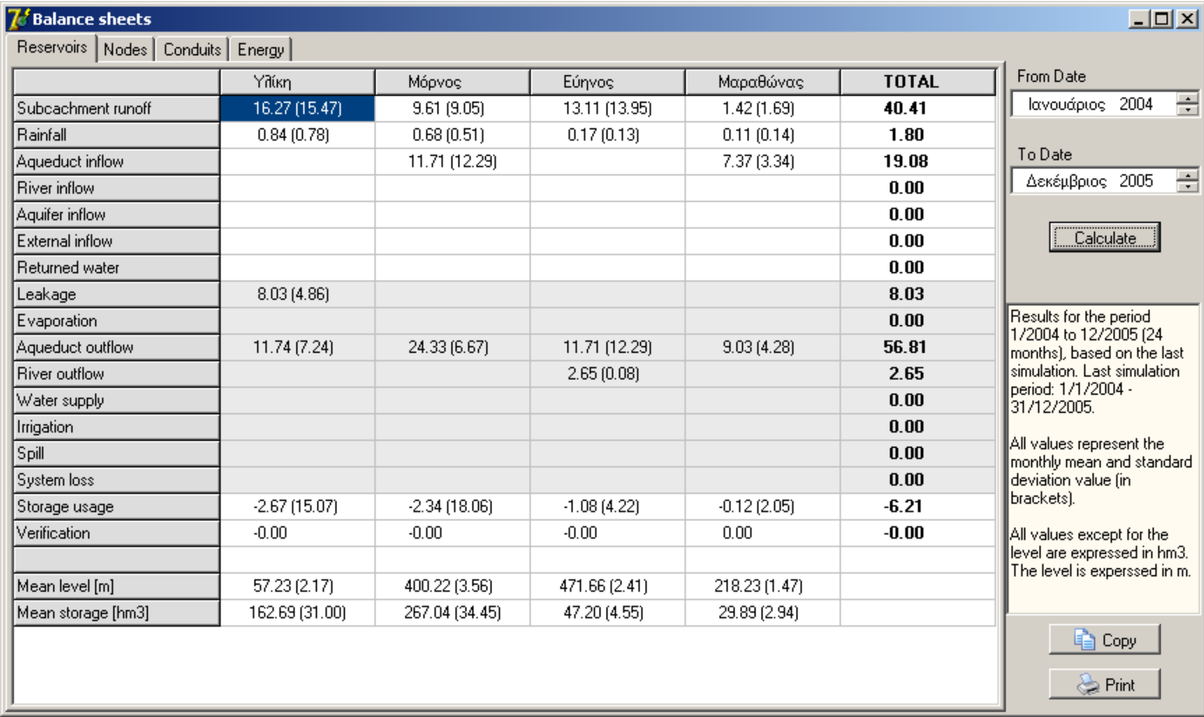
The 1st sheet of the balance form includes the water balance of each reservoir. All values, other than the value of level, are mentioned in cubic meters and are mean monthly values, while standard deviations are provided in parenthesis. More particularly, the table shows in the first line the hydrosystem's reservoirs, and the following lines list the following data:

Inflows

- **Subcatchment runoff**: Inflow to the reservoir from its watershed.
- **Rainfall**: Rainfall on the reservoir's surface.
- **Aqueduct inflow**: Total inflows from upstream aqueducts.
- **River inflow**: Total inflows from upstream rivers.
- **Aquifer inflow**: Total inflows from boreholes.
- **External inflow**: Total inflows from other sources.
- **Returned water**: Total quantity of water returned to the hydrosystem through the reservoir after a use to meet water consumption targets.

Outflows (on grey background)

- **Leakage**: Underground leaks.
- **Evaporation**: Surface evaporation.
- **Aqueduct outflow**: Outflows to downstream aqueducts.
- **River outflow**: Outflows to downstream rivers.
- **Water supply**: Consumption of water for water supply purposes.
- **Irrigation**: Consumption of water for irrigation purposes.
- **Spill**: Spills from the reservoir.
- **System loss**: Outflow from the hydrosystem
- **Storage usage**: The balance is closed by the (positive or negative) difference of volume between the beginning and the end of the simulation.



Balance sheets

Reservoirs | Nodes | Conduits | Energy

	Υλίκη	Μόρνος	Εύηνος	Μαραθώνας	TOTAL
Subcachment runoff	16.27 (15.47)	9.61 (9.05)	13.11 (13.95)	1.42 (1.69)	40.41
Rainfall	0.84 (0.78)	0.68 (0.51)	0.17 (0.13)	0.11 (0.14)	1.80
Aqueduct inflow		11.71 (12.29)		7.37 (3.34)	19.08
River inflow					0.00
Aquifer inflow					0.00
External inflow					0.00
Returned water					0.00
Leakage	8.03 (4.86)				8.03
Evaporation					0.00
Aqueduct outflow	11.74 (7.24)	24.33 (6.67)	11.71 (12.29)	9.03 (4.28)	56.81
River outflow			2.65 (0.08)		2.65
Water supply					0.00
Irrigation					0.00
Spill					0.00
System loss					0.00
Storage usage	-2.67 (15.07)	-2.34 (18.06)	-1.08 (4.22)	-0.12 (2.05)	-6.21
Verification	-0.00	-0.00	-0.00	0.00	-0.00
Mean level [m]	57.23 (2.17)	400.22 (3.56)	471.66 (2.41)	218.23 (1.47)	
Mean storage [hm3]	162.69 (31.00)	267.04 (34.45)	47.20 (4.55)	29.89 (2.94)	

From Date: Ιανουάριος 2004

To Date: Δεκέμβριος 2005

Calculate

Results for the period 1/2004 to 12/2005 (24 months), based on the last simulation. Last simulation period: 1/1/2004 - 31/12/2005.

All values represent the monthly mean and standard deviation value (in brackets).

All values except for the level are expressed in hm3. The level is expressed in m.

Copy

Print

The lower part of the balance table provides the mean storage and the mean level of reservoirs (in meters) during the simulation.

7.3.2 Node Balance

The second sheet provides the water balance of network's nodes divided in two categories: a) river nodes and b) aqueduct junctions. All values are mentioned in cubic meters and are mean monthly values, while standard deviations are provided in parenthesis. In particular, the first column of the table includes the nodes of the hydrosystem's model. The following columns list the inflows and outflows of the nodes as follows:

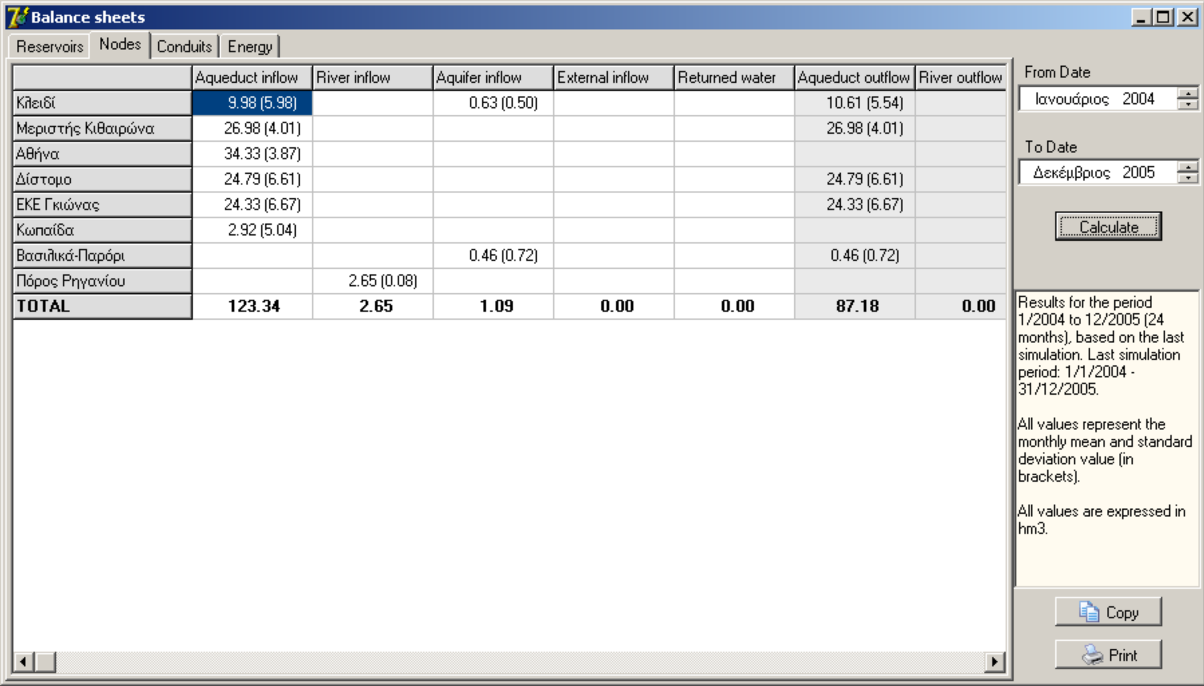
Inflows

- **Aqueduct inflow**: Total inflows from upstream aqueducts.
- **River inflow**: Total inflows from upstream rivers.
- **Aquifer inflow**: Total inflows from boreholes.
- **External inflow**: Total inflows from other sources.
- **Returned water**: Total quantity of water returned to the hydrosystem through the reservoir after a use to meet water consumption targets.

Outflows (on grey background)

- **Aqueduct outflow**: Total outflows to downstream aqueducts.
- **River outflow**: Total outflows to downstream rivers.
- **Water supply**: Total consumption of water for irrigation purposes.
- **Irrigation**: Total consumption of water for supply purposes.

- **System loss**: Losses from the system.



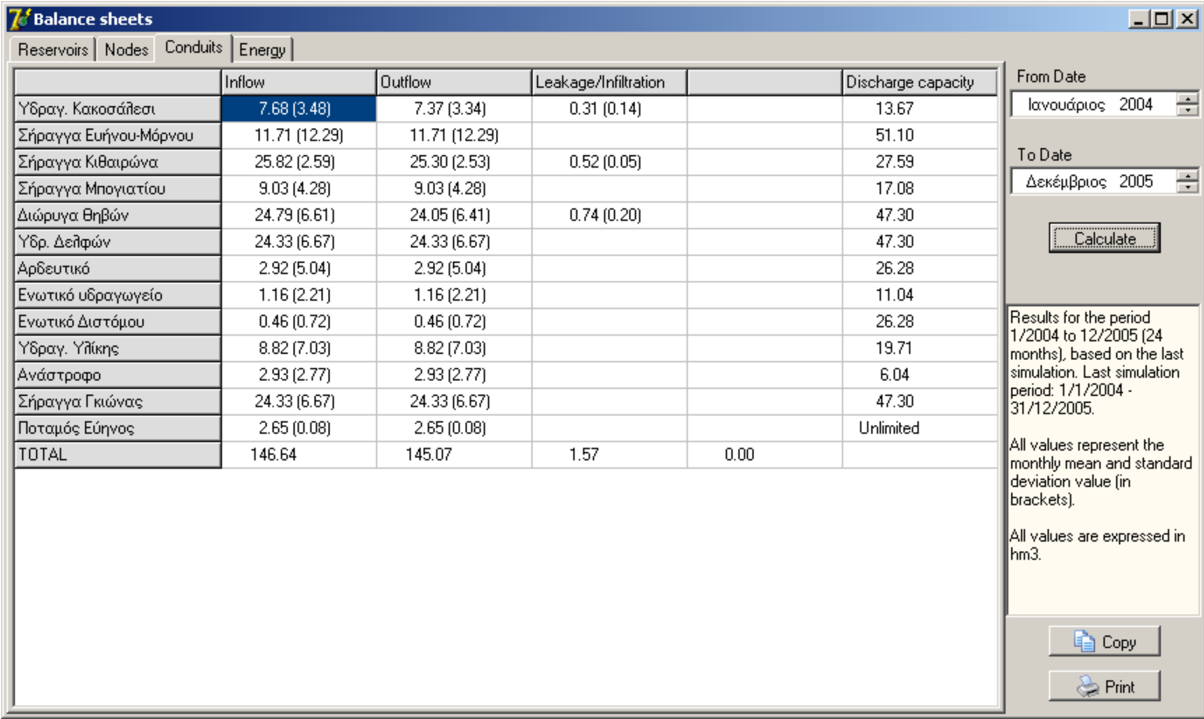
	Aqueduct inflow	River inflow	Aquifer inflow	External inflow	Returned water	Aqueduct outflow	River outflow
Κλειδί	9.98 (5.98)		0.63 (0.50)			10.61 (5.54)	
Μεριστής Κιθαιρώνα	26.98 (4.01)					26.98 (4.01)	
Αθήνα	34.33 (3.87)						
Δίστομο	24.79 (6.61)					24.79 (6.61)	
ΕΚΕ Γκιώνας	24.33 (6.67)					24.33 (6.67)	
Κωπαΐδα	2.92 (5.04)						
Βασιλικά-Παρόρι			0.46 (0.72)			0.46 (0.72)	
Πόρος Ρηγανίου		2.65 (0.08)					
TOTAL	**123.34**	**2.65**	**1.09**	**0.00**	**0.00**	**87.18**	**0.00**

7.3.3 Aqueduct and river balance

The third sheet shows the water balance of each river and aqueduct of the network, including water conduits through pumping (pump stations) or hydroelectric power generation (turbines). All values are mentioned in cubic meters and are mean monthly values, while standard deviations are provided in parenthesis.

The table shows in the first column the conduits of the hydrosystem's model, and the following columns list the following data:

- **Inflow**: Total inflows from upstream aqueduct or river.
- **Outflow:** Total outflows to downstream aqueduct or river.
- **Leakage/Infiltration**: Leakage (of the aqueduct) or infiltrations (of the river).
- **Discharge capacity**: The final column provides, in the case of aqueducts, the mean monthly discharge capacity in cm^3.



	Inflow	Outflow	Leakage/Infiltration		Discharge capacity
Υδραγ. Κακοσάλεσι	7.68 (3.48)	7.37 (3.34)	0.31 (0.14)		13.67
Σήραγγα Ευήνου-Μόρνου	11.71 (12.29)	11.71 (12.29)			51.10
Σήραγγα Κιθαιρώνα	25.82 (2.59)	25.30 (2.53)	0.52 (0.05)		27.59
Σήραγγα Μπογιατίου	9.03 (4.28)	9.03 (4.28)			17.08
Διώρυγα Θηβών	24.79 (6.61)	24.05 (6.41)	0.74 (0.20)		47.30
Υδρ. Δελφών	24.33 (6.67)	24.33 (6.67)			47.30
Αρδευτικό	2.92 (5.04)	2.92 (5.04)			26.28
Ενωτικό υδραγωγείο	1.16 (2.21)	1.16 (2.21)			11.04
Ενωτικό Διστόμου	0.46 (0.72)	0.46 (0.72)			26.28
Υδραγ. Υλίκης	8.82 (7.03)	8.82 (7.03)			19.71
Ανάστροφο	2.93 (2.77)	2.93 (2.77)			6.04
Σήραγγα Γκιώνας	24.33 (6.67)	24.33 (6.67)			47.30
Ποταμός Εύηνος	2.65 (0.08)	2.65 (0.08)			Unlimited
TOTAL	146.64	145.07	1.57	0.00	

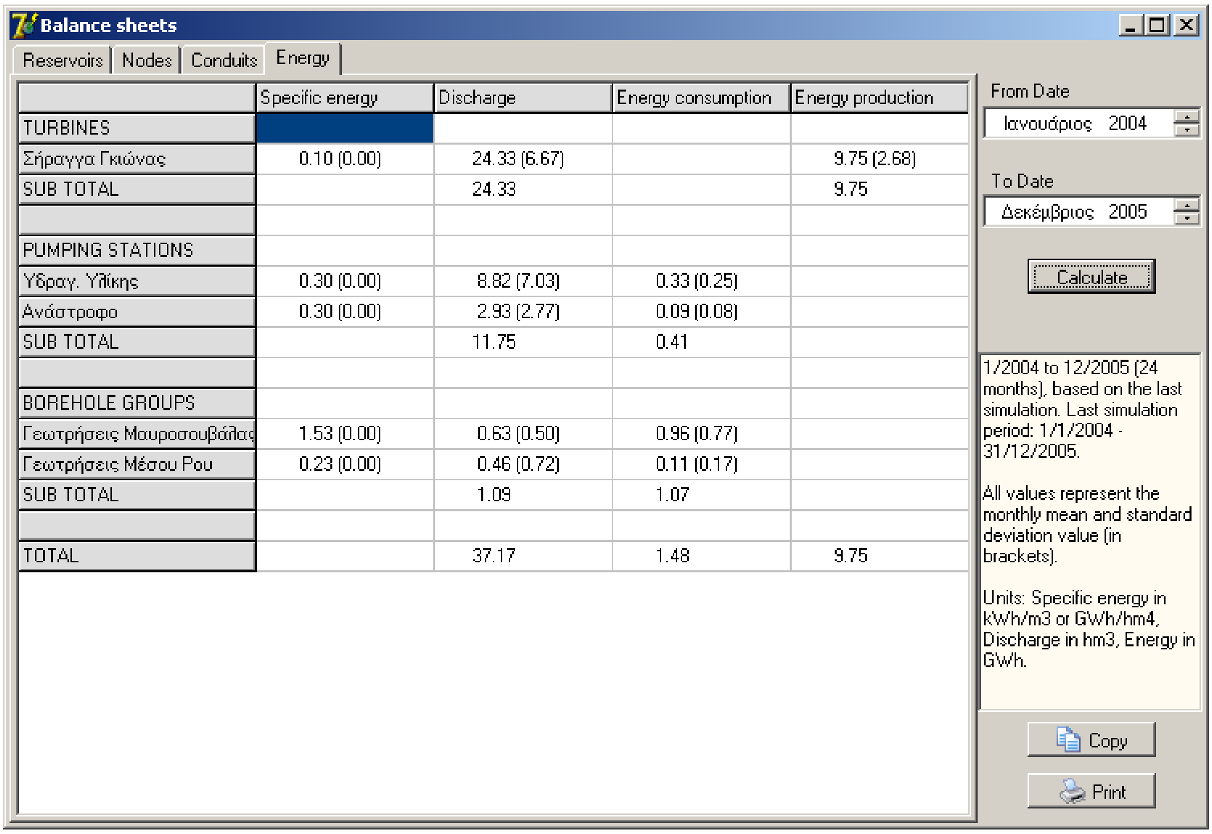
7.3.4 Energy balance

The forth and last sheet of the form analyzes energy production and consumption during hysdrosystem operation. More particularly, the table is divided in three parts: a) **Turbines**, b) **Pumps** and c) **Boreholes/Borehole groups**. The last two categories are energy consumers, while the first category is related to energy production. All values are mean monthly values, while standard deviations are provided in parenthesis.

The table shows in the first column the hydrosystem's energy units, and the following columns list the following data:

- **Specific energy**: Specific energy in kWh/m^3 for boreholes and in GWh/hm^4 for turbines and pump stations.
- **Discharge**: Water discharge from the unit in cm^3.
- **Energy consumption**: Energy consumption in GWh.
- **Energy production**: Hydroelectric energy production in GWh.

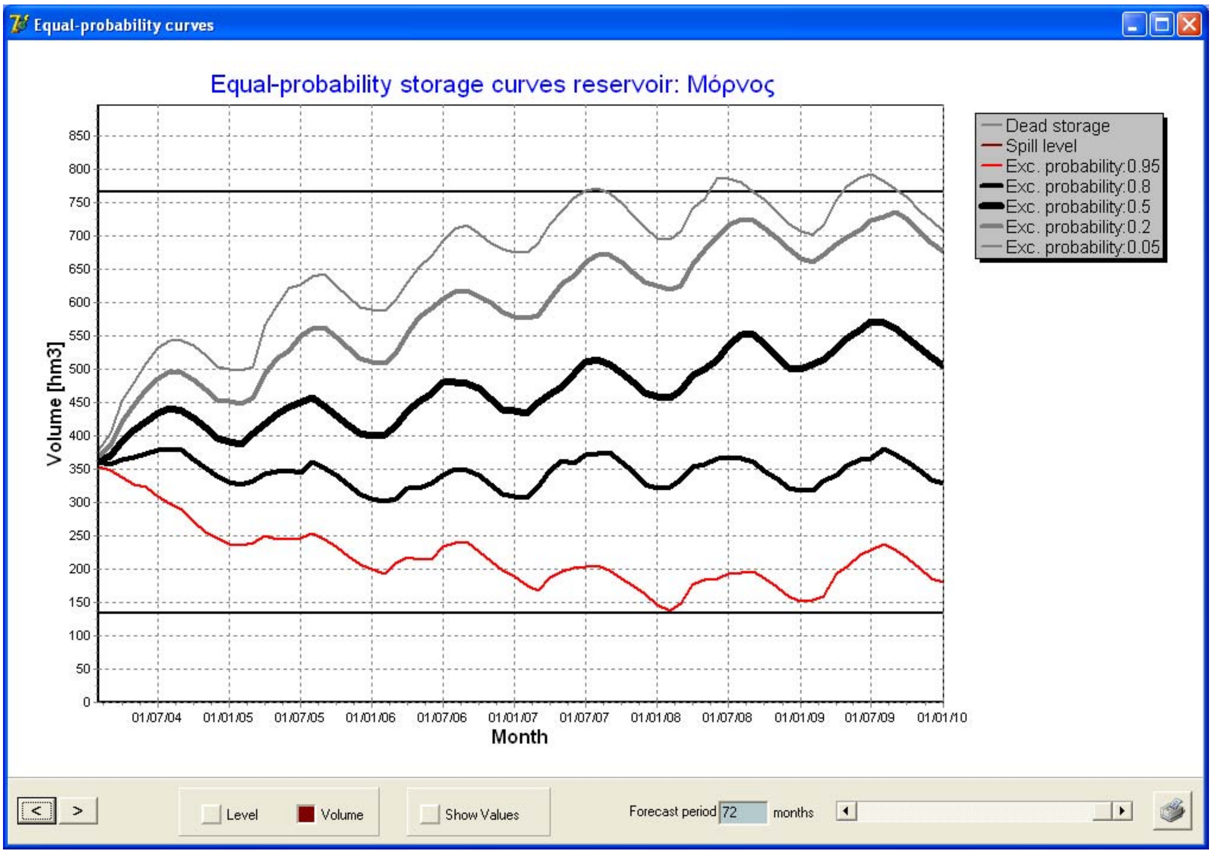
Sub totals and **Totals** are provided both for the production and for the consumption of energy.



	Specific energy	Discharge	Energy consumption	Energy production
TURBINES				
Σήραγγα Γκιώνας	0.10 (0.00)	24.33 (6.67)		9.75 (2.68)
SUB TOTAL		24.33		9.75
PUMPING STATIONS				
Υδραγ. Υλίκης	0.30 (0.00)	8.82 (7.03)	0.33 (0.25)	
Ανάστροφο	0.30 (0.00)	2.93 (2.77)	0.09 (0.08)	
SUB TOTAL		11.75	0.41	
BOREHOLE GROUPS				
Γεωτρήσεις Μαυροσουβάλας	1.53 (0.00)	0.63 (0.50)	0.96 (0.77)	
Γεωτρήσεις Μέσου Ρου	0.23 (0.00)	0.46 (0.72)	0.11 (0.17)	
SUB TOTAL		1.09	1.07	
TOTAL		37.17	1.48	9.75

7.4 Prediction of reservoir stock and level

From the menu of the Main Form, if you select **Results/Storage Prediction,** the form of reservoir storage equiprobable curves appears, which provides the estimated level and storage of hysdrosystem's reservoirs in terms of time, in relation to a probability of excess (of level or storage). In particular, five equiprobable level or storage curves are presented, which correspond to excess probabilities of 5%, 20%, 50%, 80% and 95%. .



Note: For the calculation of equiprobable curves, the results from all hydrological scenarios simulated are analyzed. In case where only one hydrological scenario has been simulated, there is no difference between curves which are identical. The number of simulation hydrological scenarios is determined in the Options Form.

On the lower part of the form, the user can show the relevant equiprobable curves using the **Level** and **Volume** commands. Clicking the < and > buttons, the user can jump to the previous and the next reservoir. On the lower right part of the form, using the scroll bar, the user can limit the timeframe **(Forecast period)** of the graph, and using the **Show values** command, the user can show in the graph the level values (in m) or the storage values (in hm^3). By clicking the print button, the user can send the form to the default printer.

Part VIII

8 References

- Efstratiadis, A., D. Koutsoyiannis, and D. Xenos, Minimising water cost in the water resource management of Athens, Urban Water Journal, 1(1), 3-15, 2004.
- Efstratiadis, A., and D. Koutsoyiannis, An evolutionary annealing-simplex algorithm for global optimisation of water resource systems, Proceedings of the Fifth International Conference on Hydroinformatics, Cardiff, UK, 1423-1428, International Water Association, 2002.
- Koutsoyiannis, D., A. Efstratiadis, and G. Karavokiros, A decision support tool for the management of multi-reservoir systems, Journal of the American Water Resources Association, 38(4), 945-958, 2002.
- Koutsoyiannis, D., and A. Economou, Evaluation of the parameterization-simulation-optimization approach for the control of reservoir systems, Water Resources Research, 39(6), 1170, 1-17, 2003.
- Koutsoyiannis, D., G. Karavokiros, A. Efstratiadis, N. Mamassis, A. Koukouvinos, and A. Christofides, A decision support system for the management of the water resource system of Athens, Physics and Chemistry of the Earth, 28(14-15), 599-609, 2003.
- Nalbantis, I., and D. Koutsoyiannis, A parametric rule for planning and management of multiple reservoir systems, Water Resources Research, 33 (9), 2165-2177, 1997.

Partners of H Y D R O G A E A are

National Technical University of Athens
Department of Water Resources
Iroon Polytechneiou 5, 15780 Zografou
http://www.hydro.ntua.gr

NAMA Consulting Engineers and Planners SA
Perrikou 32, 11524 Athens
http://www.namanet.gr

Marathon Data Systems
Kifisias 38 Avenue, 15125 Paradeisos Amarousiou - Athens
http://www.marathondata.gr