Contents

1. Introduction

1.1 Duflow Modelling Studio

The Duflow Modelling Studio (DMS) supplies the water authorities with a complete set of tools, to quickly perform easy analysis. On the other hand, the product is also capable of performing complex, integral studies.

Duflow Modelling Studio consists of the following components:

- DUFLOW water quantity and quality
  With this program one can perform unsteady flow computations in networks of open water courses. DUFLOW is also useful in simulating the transportation of substances in free surface flow and more complex water quality processes.
- RAM precipitation runoff module
  With ram one can calculate the supply of rainfall to the surface flow. Ram calculates the losses and delays that occur before the precipitation has reached the surface flow.
- MODUFLOW (not implemented in DMS version 1.0)
  This program simulates an integrated ground water and surface water problem by combining the ground water model Modflow and DUFLOW.

The possibility of entering component specific data depends on the installed components. The User's Guide gives a complete instruction about all data which can be entered in Duflow Modelling Studio when all components are installed.

1.1.1 Scenario Manager

With the Scenario Manager the user can easily define different scenarios which are based on the first created model. As default the data of each scenario is equivalent to the base scenario. The user can however easily alter the data for each scenario without affecting the data of the base scenario. By calculating the different scenarios and comparing the results the user can evaluate the effects of the scenarios on the model.

The Scenario Manager window displays a project-tree of the opened projects and scenarios.

1.1.2 Network editor

The Network editor of DMS offers the user a tool for creating a model in a user-friendly way. The network editor is a graphical editor that enables you to interactively draw the network schematization. The desired object (e.g. a node) can easily be selected from the Palette toolbar. The mouse is used to place the object in the network window. This network editor is based on the Standard Exchange Format (dutch: Standaard Uitwisselings Formaat - SUF), which has consequences for the way in which the network is set up.

In the standard exchange format, a schematization is built up of nodes, sections and objects defined on these sections.

- Nodes are points at which one or more sections arise or end.
- A section connects two nodes.
- Objects that can be defined on sections are: structures, cross sections, discharge points, etc.

Different kind of objects like structures, area points, discharge points and objects containing cross-sectional data can be defined on a section.

The schematization is set up and adjusted by selecting and dragging the objects.

By selecting objects from the Network Window, one can activate the Object Properties dialog box, where the properties of these objects can be modified.

Cross-sections can be applied on miscellaneous places on the section. The cross sectional profile over the entire section is interpolated between the different cross sections given by the user.

1.1.3 Presentation of the results

The DUFLOW interface is supplied with an elaborate presentation module. The presentation model is designed to give the user optimal support for interpretation of the results.

Some possibilities of the presentation module with respect to plotting are:

- Boundary conditions can be plotted in the same graph as the results.
- Output facility to tables, makes it possible to import the results into a spreadsheet for further post processing.
- Local values can be read by a so-called hair line. Selecting a point on the graph with the mouse activates a vertical line in the graph window. The values of the active graphs in the graph window are printed in the legend.
- Aside from plotting the quantities with respect to time, one can also plot graphs with respect to space. For space related output the user can define the route by using the sections as defined in the network editor.

It is also possible to spatially visualise the results of the DUFLOW calculation with Presentation scripts.

1.1.4 DMS compared to Duflow 2.0x

The network schematization in DMS can be used by each installed component like DUFLOW or RAM. This network can be easily build and changed by using the Network editor. The network schematization in DMS is based on the Standard Exchange Format. Therefore a DMS-schematization differs from the schematization as used in DUFLOW 2.0x. DMS can import the Network-files from a DUFLOW 2.0x project and converts it to a DMS-schematization.

In DMS cross-sections can be defined at any location on a section and not only at the begin or end of the section like in DUFLOW 2.0x. The bottom level is defined in a cross-section scheme.

To calculate a model the DMS schematization is converted to the DUFLOW 2.0x files which can be read by the file Cduflo.exe. The numbers of the nodes and sections in these files don't correspond with the object-ID's of the DMS schematization !

1.2 Hardware and Software Requirements

System requirements for using the Duflow Modelling Studio on the Personal Computer are:

- minimal 486, suggested is a Pentium
- minimal 16 Mb internal memory, a minimum of 24 Mb is recommended
- minimal 50Mb external memory

Software requirements for running the Duflow Modelling Studio are:

- Windows95 or WindowsNT (4.00 or higher)

1.3 Installation

The Duflow Modelling Studio consists of installation disks or a CD-ROM plus a User's Guide and Reference Manuals for each component.

For installing a component of the Duflow Modelling Studio (DUFLOW, RAM or Moduflow) a password is needed.

Before starting the installation procedure of the Duflow Modelling Studio, close as many opened applications as possible. The program makes use of several files (dll, ocx) which might be used by other applications. The set-up procedure will not be able to renew these files if they are in use.

The Duflow Modelling Studio is installed on a personal computer by following these simple steps:

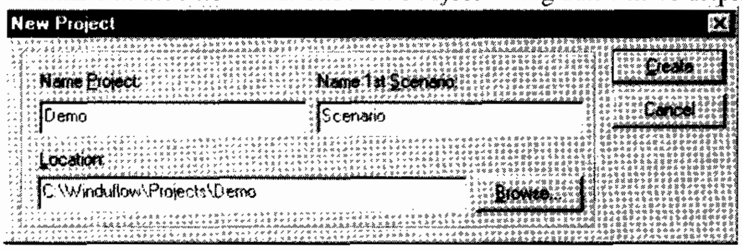
1. Choose from the startmenu **Run...**;
2. Type "**A:\Setup.exe**";
3. Follow the instructions given by the set-up procedure.

2. Getting started

In this chapter a simple problem is entered and computed in a step by step approach. This section is designed to help the beginning user to get acquainted with setting the input parameters, performing a calculation and viewing the results while using DUFLOW MODELLING STUDIO (DMS). First of all the program must be installed correctly.

2.1 Define a Project

After you have started DMS, you can define a Project by choosing the *New* command in the *File* menu. The *New Project* dialog box will be displayed.



Choose the name of a Project, say **Demo**. A sub-directory is automatically created by DMS, the location of this sub-directory may be altered in the *Location* field. By choosing *Create*, a new project is built.

DMS will now have opened the window, known as the *Scenario Manager*. This window shows all Projects currently opened, with their related Scenarios, in a tree structure. Each Scenario contains several data collections, which will appear or disappear by using the plus or minus in the tree.

 = *Show or hide the Scenario Manager*

If the Scenario Manager Window is hidden you can call it by choosing the option *Scenario Manager* in the *View* menu.

The Scenario Manager enables you to work with several sets of input data within the same Project. For example, it is possible to simulate two Scenarios having identical input data, with the exception of precipitation. This enables the user to easily evaluate the results of a severe rainstorm. The Scenario may contain the input data itself or it may refer to input data of another Scenario. Each Scenario registers several sets of data. Per set of data one may choose to save the data in its own Scenario directory or receive the data from another Scenario directory.

 = *Edit Description*

By choosing the option *Description* of the *Scenario* menu, an extended description of the scenario can be stored.

2.2 Configure the network

= *Open Network window*

By using the *Open Network window* command in the *View* menu , the Network Window is opened: Here the network schematization is created and/or interactively modified.

NB If an icon is not visible in one of the toolbars, choose *Customize...* in the *Options* menu. DMS will show the *Customize* dialog box.

The buttons of the commands belonging to the selected category are displayed on the **Command** tab. By dragging a button to a toolbar the button is added to the toolbar. By dragging it away from the toolbar, the button will be removed from the toolbar.

The Network can be build on a geographical background by first checking the option *Use geographic map as background* in the *Projects Properties* dialog box. This box appears by using the Properties command in the Project menu.

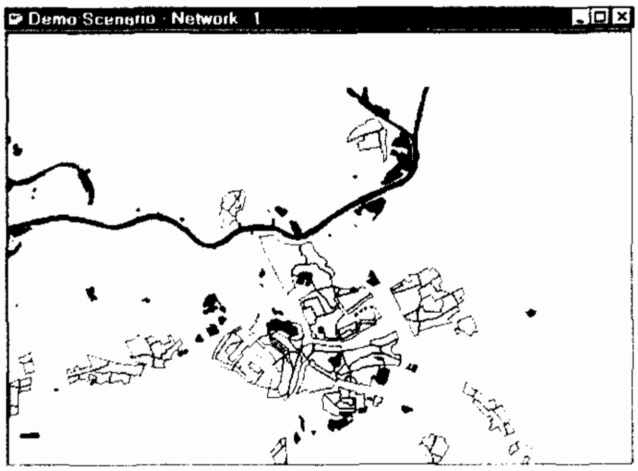
= *Display Layers*

To add layers to the Network window choose the *Display layers* icon on the Palette toolbar. DMS will show the *Display Layers* dialog box.

Use the **Add** button to add layers to the Network window. DMS will open the *Open File* dialog box. Only shape-files can be used for layers in DMS. Select the shape-file **Water.shp**[1] from the *Windflow\Projects\Shapes* directory in the *File Open* dialog box. This shape file contains the waterways of a region in the Netherlands.

When a shape-file is selected, DMS will show the *Color* dialog box to choose the right color - e.g. blue - for the selected layer. After the selection of a color DMS will return to the *Display Layers* dialog box. The order of the layers in this list correspond with the order in which the layers are displayed in the Network window. To modify this order select a layer and press the **Up** or **Down** button. Now add the **Cities.shp** file to the layers list. This file contains the cities of the region.

The Network window will look like this:



= *Zoom in*

Use the Zooming Tool to show parts of the geographical background in more detail. After selecting this command (from the menu or the toolbar) the cursor will change into a magnifying glass. Dragging the cursor displays a rectangle on the screen. This rectangle represents the area that will be magnified (the rectangle will be blown up until it fills the Network window).

[1] Geographical background: Topografische ondergrond © Topografische Dienst, Emmen. The shape-files Water.shp and Cities.shp may only be used for demonstration purposes.

 = *Save the active project*

Save your work now using the *Save* command from the *File* menu. Do this regularly !

 = *Node*

 = *Section*

By dragging the objects from the Network Palette, you can draw your network. From the palette, choose the *Node* tool and click at two positions in the Network Window. Next choose the Section tool and click the left mouse button on one of the two Nodes. Move the mouse by dragging the section towards the other Node and release the mouse button.

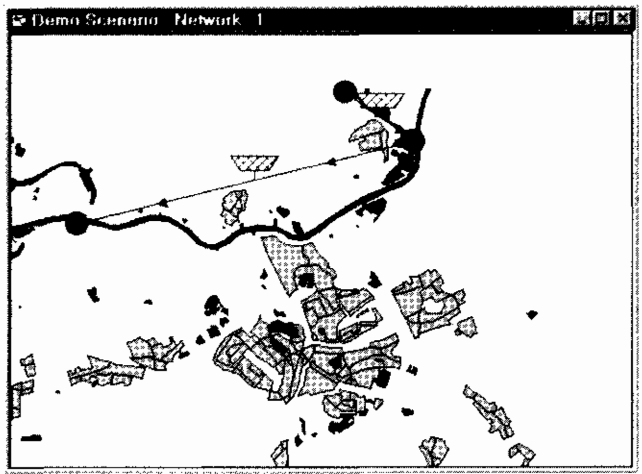
 = *Select object*

If the line between two nodes remains dotted, it means that the Nodes are not correctly connected by the Section. The Nodes can be properly connected by using the *Select* tool (the arrow) from the palette and dragging the end of the selected Section until the line is complete.

 = *Cross-section*

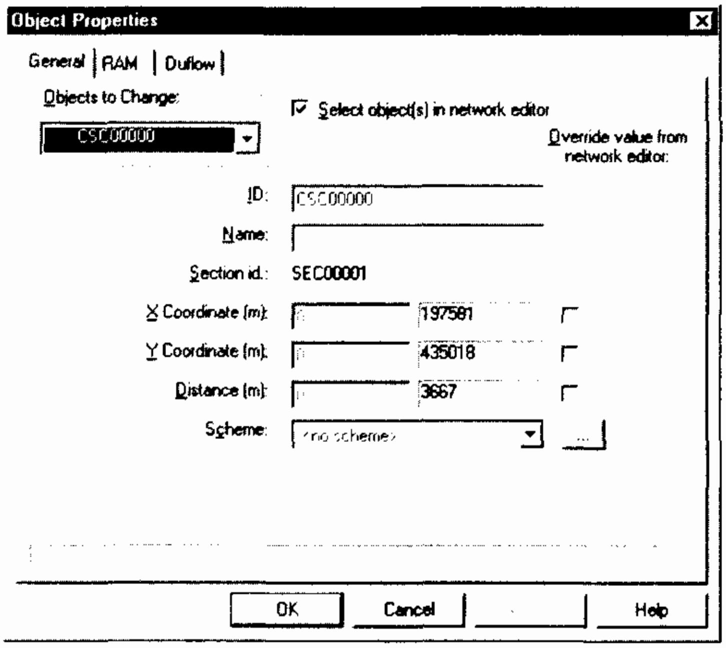
Cross Sections are added to the Section by using the *Cross-Section* tool from the palette. When the cross sectional data is connected to the section it appears blue. If the Cross-Section is not properly connected to the section, its outline will appear dotted. Until the cross-sectional data is defined, the cross-section will remain cross-hatched.

Repeat the above process until the following network is created:

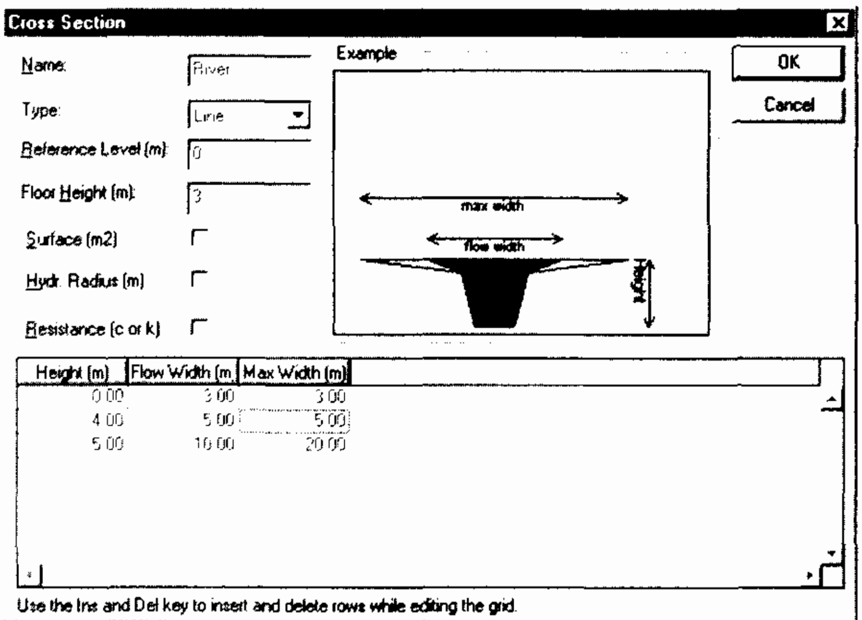


 = *Object properties*

Cross-Sections are defined by using Schemes. These Schemes must be connected to the Cross-Sections. By clicking the right mouse button on one of the Cross-Sections, choose the option *Properties* from the popup-menu.



In the *Object Properties* dialog box, the Scheme may now be connected to the Cross Section, however no Schemes are defined for this Project yet. A Scheme is created by choosing the **...** behind the *Scheme* box. In the *Cross Section Scheme* dialog box, choose **Add...** and the *Cross Section* dialog box will appear. Choose the input as shown below. To insert and delete a row in the table use the **Ins** and **Del** key.



Choose **OK**, **OK** and **OK**, the **River** Scheme has now been connected to one Cross-Section.

 = *Edit Properties of Network objects*

We are able to connect the **River** Scheme to every Cross-Section in the network by choosing the *Object Properties* option of the *Edit* menu. Again the *Object Properties* dialog box is shown, yet now it is also possible to alter several objects simultaneously.

Because DMS requires a lot of data, it allows the user to simultaneously enter data for a number of objects. In the *Objects to Change* combobox you can choose the objects you want to change.

= *Weir*

Other structures:

= *Siphon*

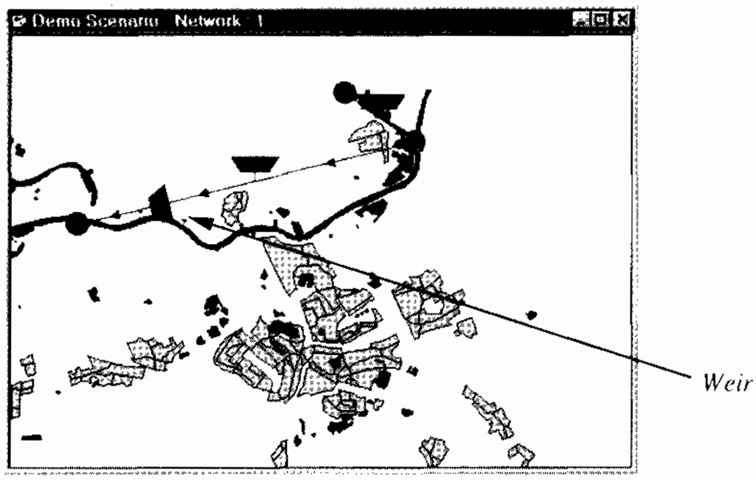
= *Culvert*

= *Pump*

= *General structure*

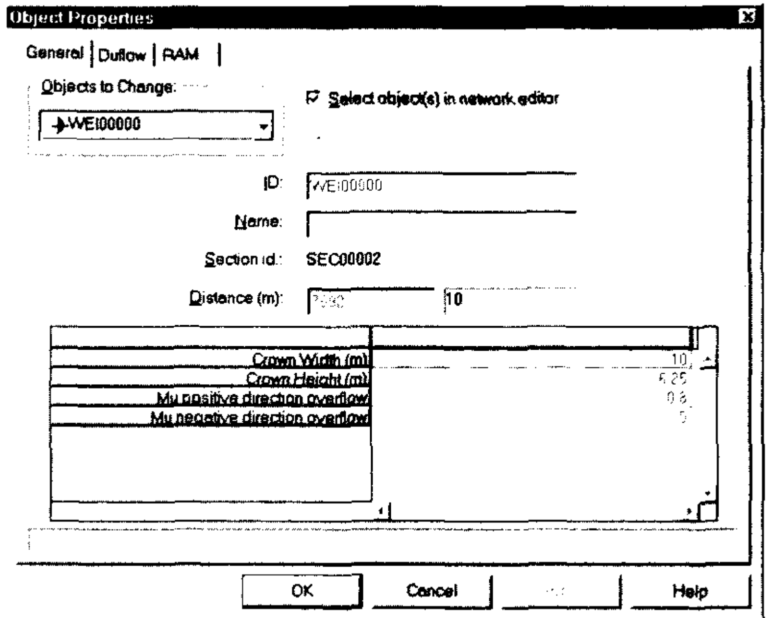
Select **All cross sections** from the *Objects to Change* combo box and behind *Scheme*, select the Scheme **River** from the pull down list box. Click **Ok** and all of the Cross-Sections in the network are connected to the same Scheme. The Cross-Sections will now appear blue.

Now add a structure - in this case a weir - to the network, by choosing the red triangle of the Network Palette and placing it into the network as follows:



In this manner a weir is added to the network on the second section. Before Duflow starts it calculation, this section will be split up into two separate sections.

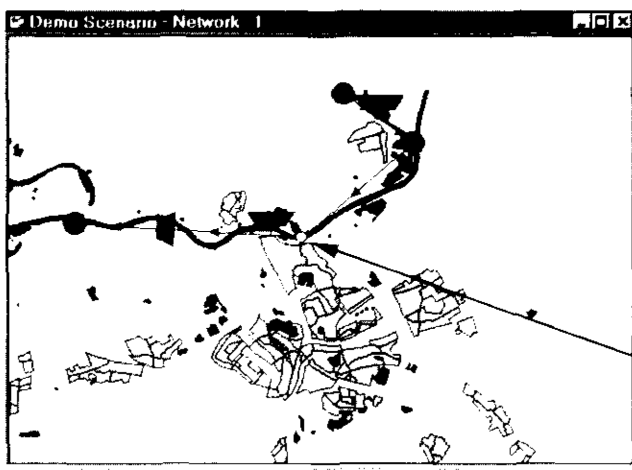
Click the right mouse button on the weir to choose the weir properties as follows:



= *Schematization point or bending point*

It is also possible to add Schematization-points to the network. Results of the calculation will be available on the Nodes, Schematization-points and calculation points. Calculation points are generated by DUFLOW when the length of a section exceeds the defined maximum length. The maximum length can be defined by the user for each section on the DUFLOW tab in the *Edit - Objects - Properties* dialog box.

Schematization points can also be used to bend a section to fit the waterway represented by the geographical background. To create a so called Bending point first add a Schematization point to a section. Then select the Schematization point and click on the right mouse button and select the option Bending point from the popup menu. By dragging the Bending point to the desired position on the waterway the section will bend and more or less 'follow' the waterway.



Bending Point

= *Discharge point*

= *Area point*

By adding a Discharge point at Schematization points you can define a time series of discharged water or wasted load or concentration. At the schematization points you can also define an area where the precipitation will be taken into account.

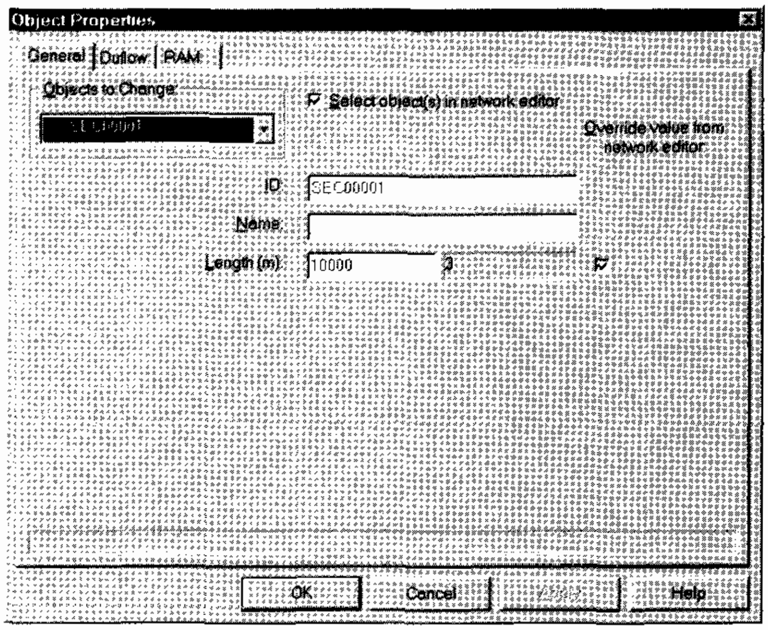
Initial conditions are added to the network by using the *Initial Conditions* command in the Scenario menu. For all Nodes and Schematization points we will now choose an initial level of 6 meters (above the reference level). Use the **Set Column...** button. Choose the column Level and enter the value.

 = *Edit Precipitation*

 = *Edit Evaporation*

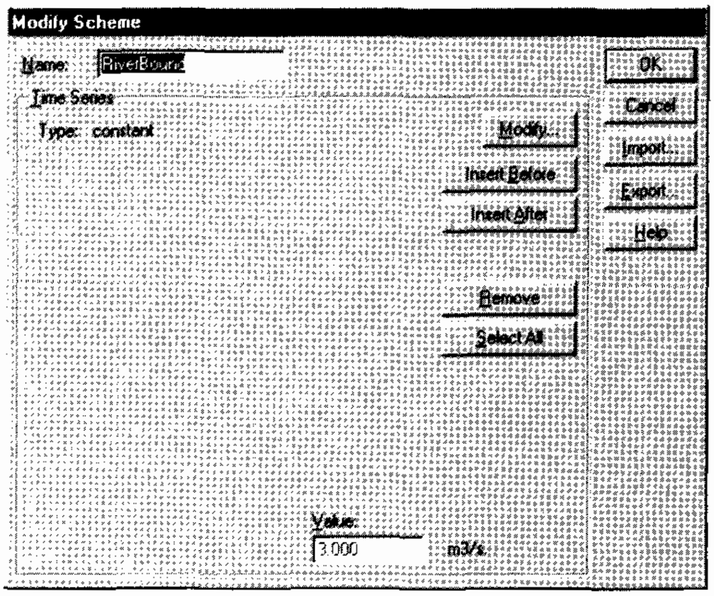
When you have defined an area at a Schematization-point you can set, modify or import a Precipitation time series by using the *Precipitation* dialog box which can be opened by choosing the option *Precipitation* in the *Scenario* menu. In the same manner you can set, modify or import evaporation time series by choosing the option *Evaporation* in the *Scenario* menu.

Right now the length of the sections is calculated by the Network editor according to the positions of the Nodes. To make the created network seem more realistic, we shall overrule these calculated lengths. For each drawn section we can alter the lengths in the *Section Object Properties* dialog box as follows:



We would now like to insert a Boundary Condition on the first Node. The Boundary Conditions can be configured by selecting the correct Node and activating the *Object Properties* dialog box for this node. Click the **Boundary Conditions...** button. The *Boundary Condition* dialog box will appear. First however Boundary Schemes need to be defined.

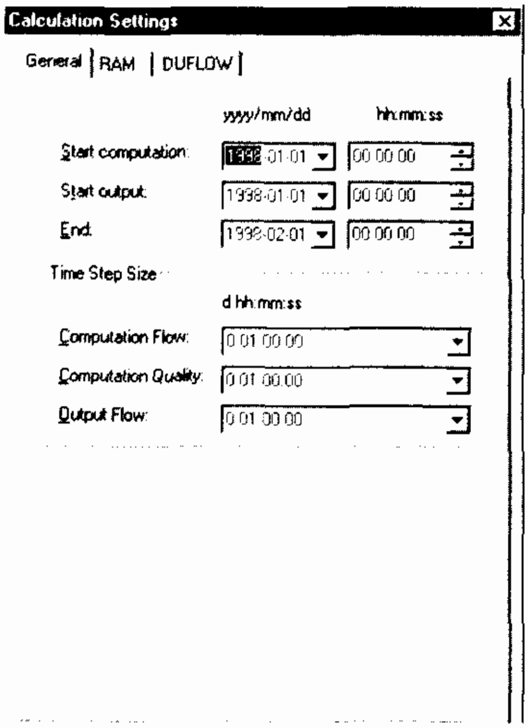
Choose to Add a *Q-Add Scheme* by clicking the **...** behind the text box. Then click the **Add...** button. The following scheme is configured:



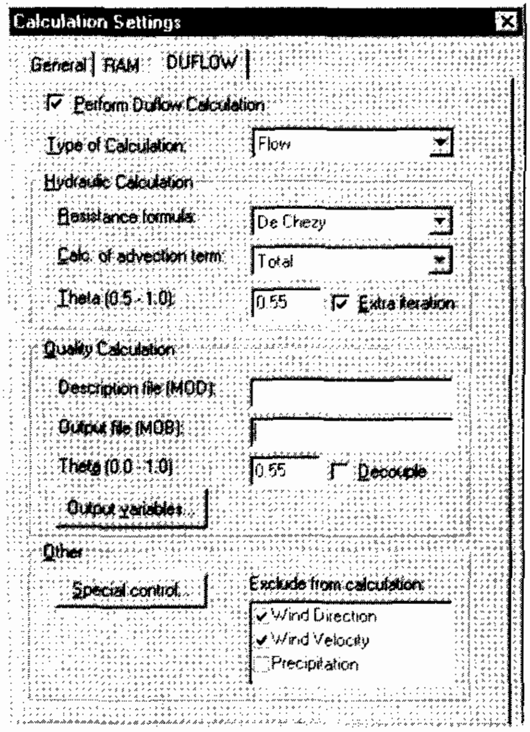
Click **OK** and **OK** and the Q-Add Scheme is now inserted on the first Node. Repeat these actions to define a constant Level of 6 metres as a Boundary Condition on the other end of the Network.

2.3 Configure and start the calculation

Before starting the calculation check the input in the *Calculation Settings* dialog box. This box is activated by clicking the right mouse button on the *Calculation Settings* in the Scenario manager. The General settings give the start of the calculation time and timestep for the flow and quality calculation. Select the following settings:



The tab DUFLOW allows you to set the Duflow specific calculation options.



The type of calculation can be chosen here. First choose a **Flow** calculation to check if the Network has been designed correctly. When the flow calculation is verified a quality model can be added. The details for the Hydraulic and Quality calculation are set in this dialog box. The Quality model definition file may be inserted here. Make sure this file is inserted in the Scenario directory.
By clicking **Output Variables...**, the variables of the quality model can be selected for output.
In Special Control the special control data are set, such as the threshold level which is the value of the water level at which the dry flood procedure is activated (Default=0.10 m).

 = *Calculate*

The calculation is activated by choosing the *Update All* option from the *Calculation* Menu (or the *Calculate* Toolbar button or the *Calculate* option from the Scenario Context menu). The *Output* window shows the initialisation of the calculation. It may be something like:

```
Starting network consistency check...
Starting Duflow conversion...
Duflow conversion completed.
Writing boundary flow file C:\Winduflow\Examples\Demo\Scenario\scenario.BND.
Writing network file C:\Winduflow\Examples\Demo\Scenario\scenario.NET
Writing initial flow file C:\Winduflow\Examples\Demo\Scenario\scenario.BEG.
Computing mode: Flow
```

The *Status Bar* shows the progress of the calculation in time steps. It may be something like:

```
Computing flow  124(  744)
```

 = *Show or hide Output*

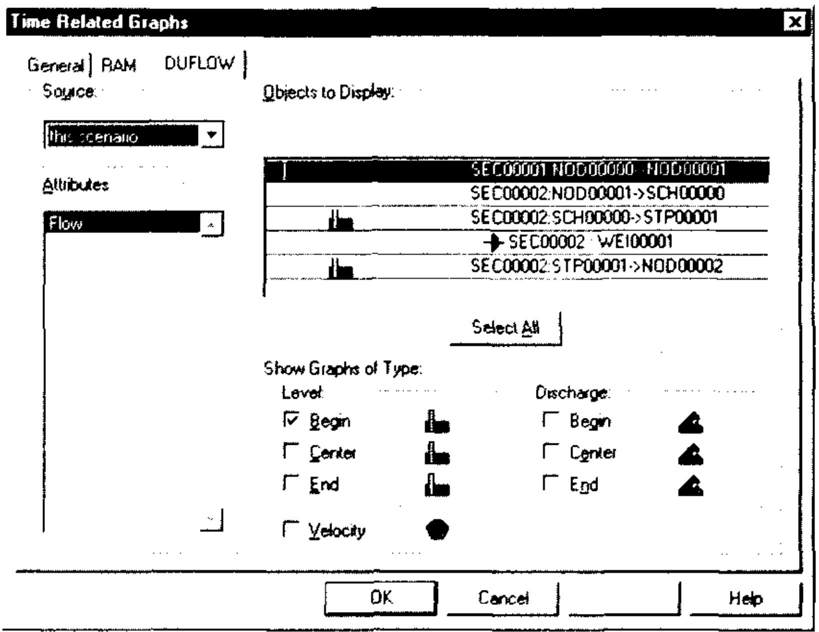
You can show (or hide) the Output window by choosing the option *Output* in de *View* menu.

2.4 Display the results

Results can be displayed in three different ways:

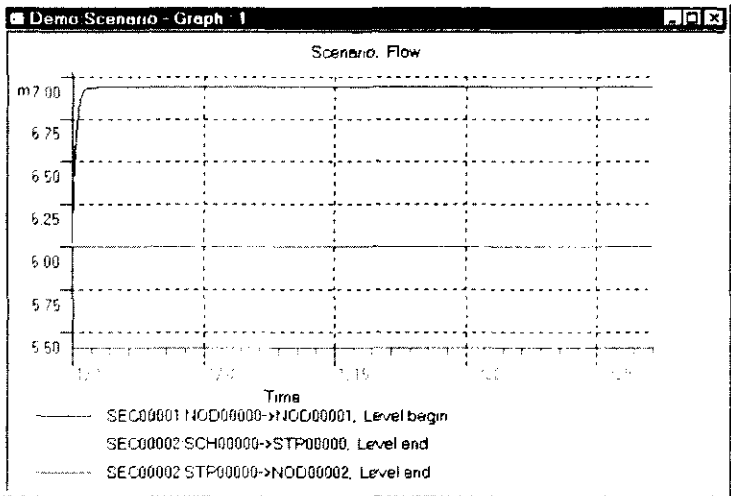
- A Time Related Graph,
- A Space Related Graph or
- Results as Text in a table as a function of time.

By choosing the *New Time Graph window* option from the Scenario Context menu, the results will be displayed in a graph as a function of time. DMS will open the *Time Related Graph* dialog box. On the DUFLOW tab you can define which variables in which sections have to be displayed.



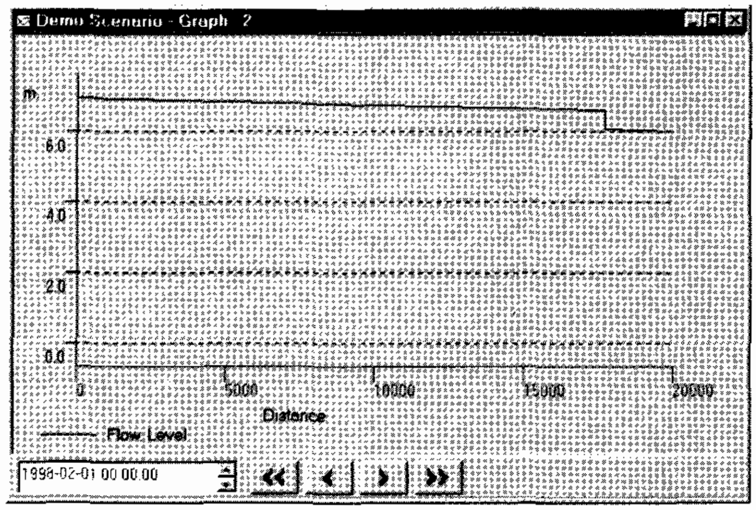
Use **Show Graphs of Type** to choose the type of graph (Level, Discharge or Velocity) of the selected objects in the **Objects to Display** list. After a selection is made, a picture representing the data type is displayed in the row(s) of the selected objects. Selection of the data type to be displayed in the graphs is also possible by clicking with the left mouse button on the left side of the row(s) of the Objects to Display list. The position in the row corresponds with the order in the data types list.

After choosing the options as displayed above, DMS will show a graph like this:



By choosing the *Space Graph window* option from the Scenario context menu, the results will be displayed as a function of space. DMS will open the *Space Related Graph* dialog box. First you have to define the route you want to display in the graph by double clicking on the sections. A route consists of one or more sections. After defining or selecting the route you can select the variables which have to be displayed. In the *Space Related Graph* window, you can move backward or forward in time by using the buttons beneath the graph.

The final Space Related graph will look like this:



For displaying the results as text in a table you have to choose the *New Text window* option from the Scenario Context menu. DMS will open the *Time Related Graph* dialog box. On the DUFLOW tab you can define which variables in which sections have to be displayed in the table.

2.5 Quality model

To add a Quality Model to an existing Flow model, the following actions need to be carried out.

2.5.1 Define the Quality Model

To add a Quality Model to the Project enter the name of the *Quality Model description* file without the extension (*.MOD) and the name of the *Quality Model Output* file without the extension (*.MOB) in the DUFLOW tab of the *Calculation Settings* dialog box. For example, enter the name 'Tracer' in both fields. If the *Quality Model* file, like in this case, does not exist in the Scenario directory, DMS will prompt you to create it.

A simple *Quality Model description* file like below contains the definition of a tracer:

```
/* DUFLOW COURSE FEBRUARY 1998                                        */
/* SIMPLE TRACERMODEL                                                  */
/* HINNE REITSMA 02-01-1998                                            */

WATER   TRAC   [10.000]   mg/l        ;TRACER

PARM    Ktrac  [0.0100]   1/day       ;DECOMPOSITION RATE TRAC

{
K1(TRAC)=-Ktrac;
}
```

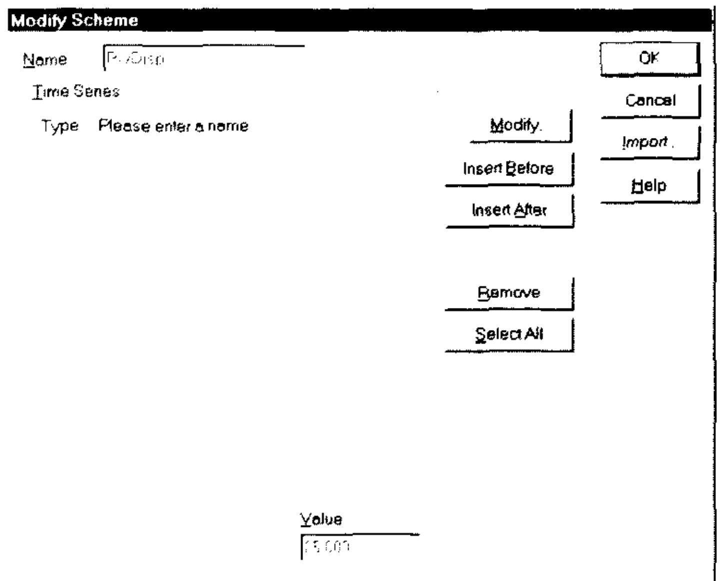
You can enter this description in the *Quality Model description* file by choosing the *Quality Model - Edit* command from the Scenario menu. If this definition is inserted correctly it can be compiled by choosing the *Quality Model Compile* command from the Scenario menu.

2.5.2 Initial Conditions

Now that the quality model is defined, we would like to enter the Initial Quality Conditions. Initial conditions are added to the network by using the *Initial Conditions* command in the *Scenario* menu. For all Nodes and Schematization points we will now choose an initial concentration for **Trac** of 10 mg/l. To do this, use the **Set Column...** button. Choose the column **Trac** and enter the value.

2.5.3 External Variables

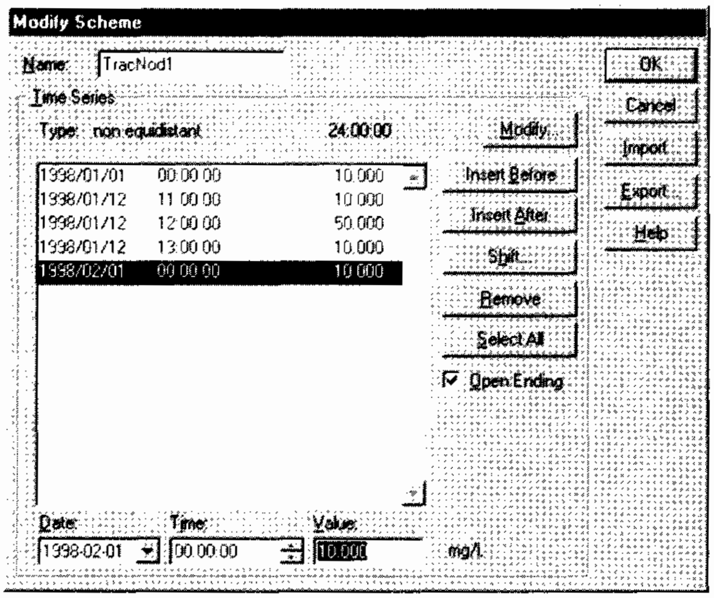
Dispersion is an external variable which has to be defined in every Quality Model. An external variable can be added by clicking the right mouse button on External variables in the Scenario Manager. Choose the external variable '**d**' from in the *Modify External Variables* dialog box and choose **Modify...**. Then choose **Add...** in the *Select Scheme* dialog box to add the following scheme for the dispersion (d).



After creating schemes for External Variables you need to define an External Variables scheme for each Node, Schematization point and Structure. In this example the scheme **RiverDisp** will be used for every object. Open the *Object Properties* dialog box by choosing the *Edit - Object - Properties*. Then select *All Nodes* and choose **External Variables...** on the DUFLOW tab. Use the **Arrow** button behind the External Variable '**d**' - which appears by selecting the input field - to select the **RiverDisp** scheme. Repeat these actions for the Schematization points and the Structures.

2.5.4 Boundary conditions

The first node must also have a Quality boundary condition. Choose the *Properties* dialog box of the first node. Choose **Boundary Conditions...** on the General tab. Choose the **...** button behind **Trac** to define a *Boundary Condition Scheme* for **Trac**. Choose **Add...** in the *Select Scheme* dialog box to add a new time series. Modify the type of boundary condition to *non-equidistant*. Enter the following timeseries:



Repeat these actions to define a constant concentration of 10 mg/l as a boundary condition on the other end of the Network. A quality boundary condition is only valid for the incoming water.

Note: A flow boundary condition without any quality boundary condition has a special meaning, which may influence the results. In normal situations it is therefore necessary to define a quality boundary condition for every flow boundary condition even if there is only outflow at the boundary.

2.5.5 Calculation Settings

Before starting the calculation, check the input in the *Calculation Settings* dialog box. This box is activated by the right mouse button on *Calculation Settings* in the Scenario manager.

Choose as *Type of calculation*: **Flow&Quality**. In *Output Variables* check the variable **Trac** of the Quality Model to be available for output.

 = *Calculate*

The calculation is activated by choosing the *Update All* option from the *Calculation* Menu (or the *Calculate* toolbar button or the *Calculate* option from the Scenario Context menu). The *Output* window and the Status bar will show the progress of the calculation.

If your model contains quality boundary conditions without flow boundary conditions warnings will generated in the *Output* window.

2.6 RAM

The actions mentioned in this paragraph can only be carried out if the RAM component has been correctly installed.

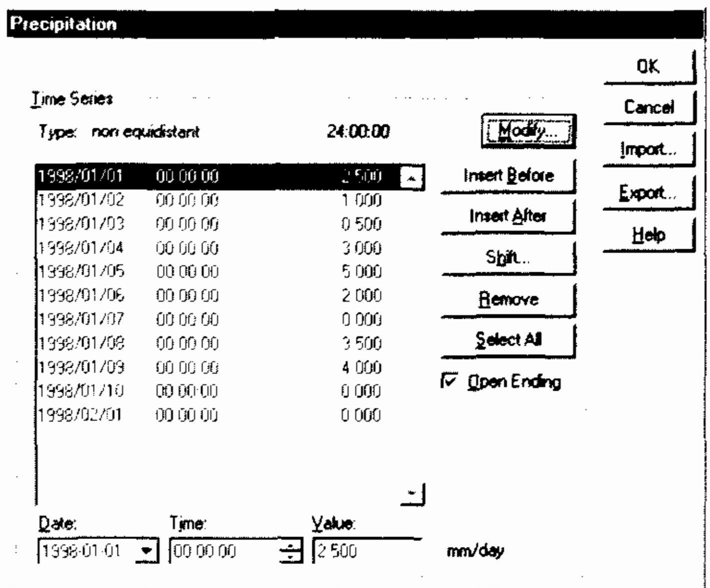
2.6.1 Precipitation and Evaporation

An important part of the input required by RAM is the precipitation and the evaporation. To enter this data please follow these instructions:

 = *Edit Precipitation*

Choose the *Precipitation* command in the Scenario Menu. DMS will show you the *Precipitation* dialog box. In this dialog box a Precipitation time series can be inserted. First click on the **Insert Before** button to enter the beginning of the time series. Next click the **Shift...** button to open the *Shift Values* dialog box and change the start date and time of the time series to January 1st, 1998 under *Set New Start Date & Time*. Back on the *Precipitation* dialog box, press the **Insert After** button. DMS will insert a new line. Repeat this action 10 times. Select the first line in the list. DMS will automatically jump to the **Value** editfield where a value for the Precipitation in mm/day can be entered.

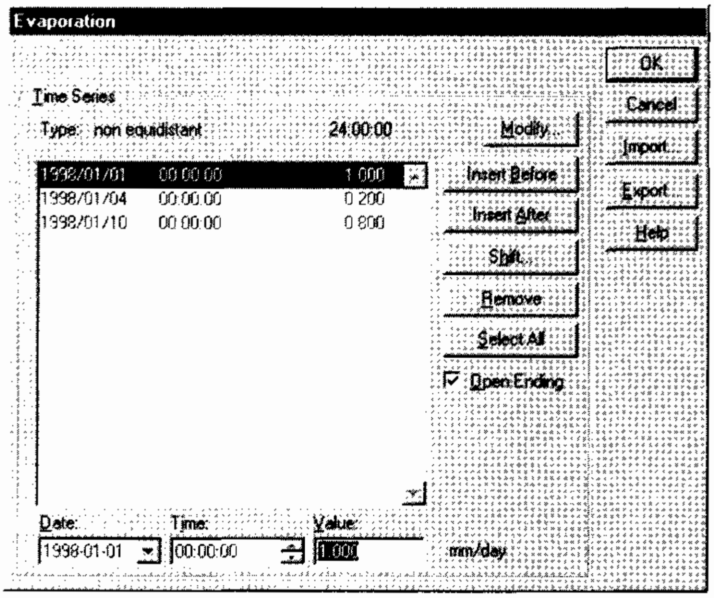
Enter the values as shown below:



We want to start our Duflow calculation in January 1998.

= Edit Evaporation

Repeat these steps for entering the Evaporation, but enter the following values:



Note: Because the date and time of the time series need to be listed in an increasing order, the final date must first be modified before altering the second date to 1998/01/04. If it is done in a different order, an error message will appear.

2.6.2 Configure the Area

= Area point

In order to calculate the runoff and the loads to a node in the network, RAM needs to know the properties of the area, around the Node, from which the runoff has to be taken into account. First you have to define an *Area* in the Network. An Area is always attached to a Schematization point. To add an Area to the Network drag the Area object from the *Palette* toolbar to the schematization point in the Network. If the Area is attached to the schematization point it will become green, otherwise it will appear dotted.

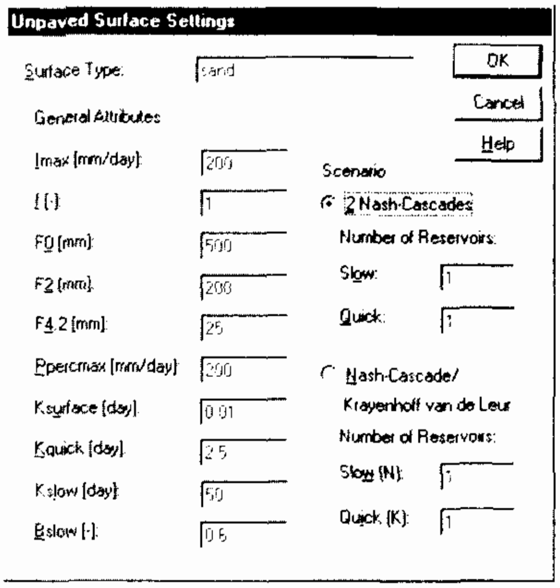
To enter the properties of the Area, doubleclick on the object in the Network window. DMS will show the *Object Properties* dialog box. On the General tab you can enter the *Total surface* of the area. In this case the surface is 10000 ha (1e+8 m^2). Select the RAM tab to insert the RAM-specific data.

The amount of data per Area is split into logical categories. A categorie can be selected in the categories listbox. Select the category *Area* and specify the percentage of *Unpaved surface* at 100%.

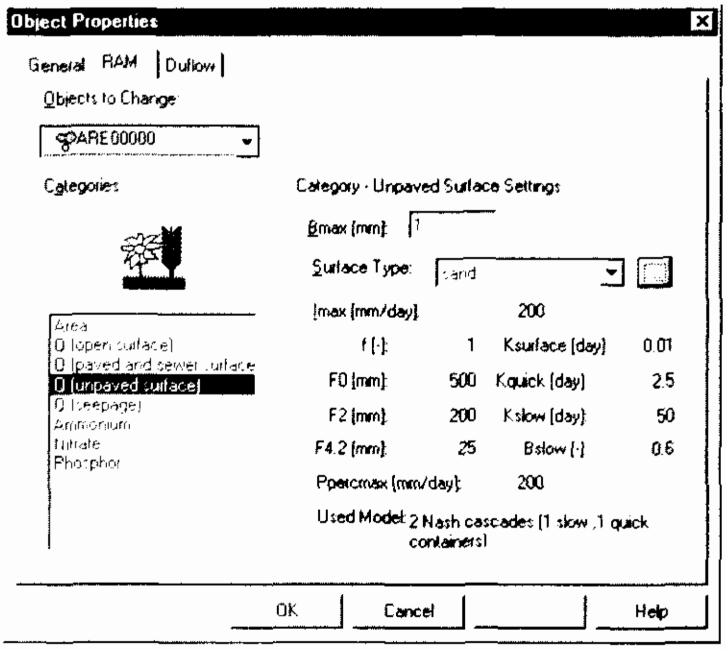
Select *Q (unpaved surface)* in the Categories listbox. DMS will display the *Unpaved Surface* settings at the right side of the dialog . Because the *Unpaved Surface* settings are rather extensive and because they depend on the type of surface of the node, RAM works with schemes. This enables one to simply reuse the *Unpaved Surface* settings for other Nodes.

Choose the **[...]** button at the right side of Surface type. DMS will show the *Select Unpaved Surface Scheme* dialog box. Since there are no schemes available, a new one must be added.

Choose the **Add...** button. DMS will display the *Unpaved Surface Settings* dialog box. Enter the following values:



Press the **OK** button. Press the **OK** button in the *Select Unpaved Surface Scheme* dialog box. DMS will show the values of the Unpaved Surface scheme in the *Objects Properties* dialog box when the categorie *Q (Unpaved surface)* is selected.



You can enter data for the other categories following the same strategy. In case of Ammonium, Nitrate and Phosphor, RAM also uses schemes. These schemes are in fact time series and can be entered using dialog boxes which have a similar appearance as the *Precipitation* and *Evaporation* dialog box.

2.6.3 Calculation

Before starting the calculation check the input in the *Calculation Settings* dialog box. This box is activated by the right mouse button on the *Calculation Settings* in the Scenario manager. The General settings give the start calculation time and timestep for the flow and quality calculation. Select as calculation period the same period as used in the time series for the Precipitation and the Evaporation (from 1 to 10 January 1998).

On the RAM tab choose the option *Perform RAM Calculation*. The option *Perform Duflow Calculation* on the Duflow tab will be disabled at the same time.

 = *Calculate*

The calculation is activated by choosing the *Update All* option from the *Calculation* Menu (or the *Calculate* toolbar button or the *Calculate* option from the Scenario Context menu). The *Output* window shows the progress of the calculation.

After the calculation, RAM has generated a boundary condition for the additional discharge on the schematization point to which the Area is attached. To show these boundary condition double-click on the Area in the Network window. DMS will open the *Object Properties* dialog box. Click on the **Boundary Conditions ...** button. Click **...** behind the QAdd scheme which is made by DMS. Choose **Modify...** to display the time series which represents the boundary condition.

When a Duflow calculation is performed again the results will differ.

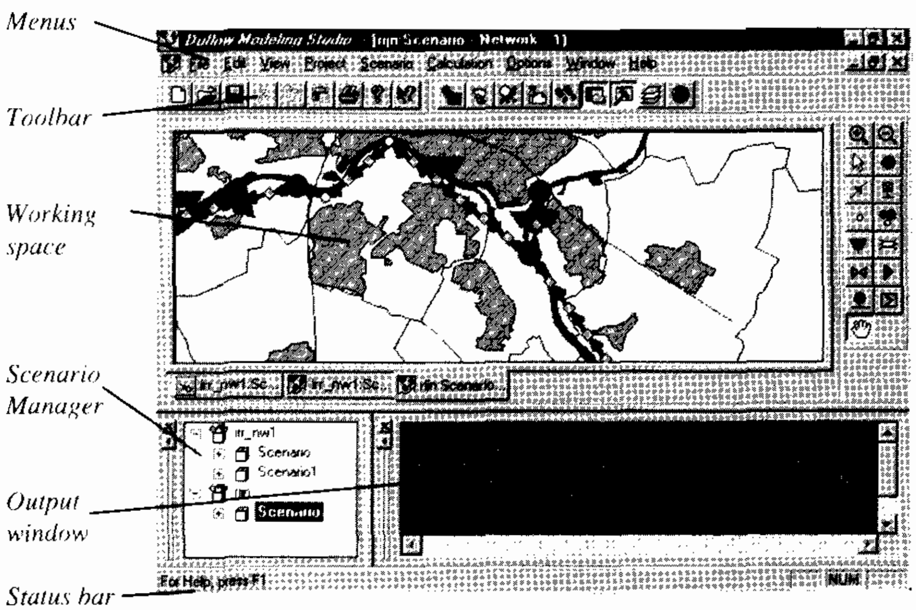
When a Duflow calculation is performed after a RAM calculation, the Precipitation must be excluded from the Duflow calculation (*Calculation Settings* - Duflow tab), otherwise the Precipitation will be taken into account twice.

3. User Interface

3.1 User interface components

The user interface of the DUFLOW Modelling Studio (DMS) consists of the following components:

- Menus
- Toolbars
- Status Bar
- Scenario Manager window
- Working space with the Network window and Results windows
- Output window



3.2 Menus

DMS contains the following menus

- File
- Edit
- View
- Project
- Scenario
- Calculation
- Options
- Window
- Help

3.2.1 File menu

The File menu offers the following commands:

New...	Creates a new set of input- and output-files (a new Project).
Open...	Opens an existing Project File.
Close	Closes an opened Project.
Save	Saves a Project File using the same file name.
Save As...	Saves a Project File to a specified name.
Import...	Imports an existing DUFLOW project files made in a DOS-version.
Print...	Prints the contents of the active view.
Print Preview	Displays the project contents on the screen as it would appear printed.
Print Setup...	Selects a printer and printer connection.
Recently opened Files (1-6)	Opens the selected project from the list with the most recently opened projects.
Exit	Exits the DUFLOW Modelling Studio.

3.2.2 Edit menu

The Edit menu offers the following commands:

Undo	Undoes the last action (not all actions can be undone).
Cut	Cuts the selection.
Copy	Copies the selection.
Paste	Pastes the selection.
Objects ▸	
Properties...	Edits the properties of all network objects.
Select...	Checks the nodes. for selection.
Graphs...	Sets display options per node.
Colors...	Configures the colors of the Graph Windows.
Window properties...	Sets the display properties of the Network Window or the Graph window.
Presentation Mode	Sets the script for the presentation mode.
Presentation Scripts...	Edits all presentation scripts schemes.

Editable	Allows or prohibits changes in the Network Window.

3.2.3 View menu

The View menu offers the following commands:

Toolbar	Shows or hides the toolbar.
Status Bar	Shows or hides the status bar.
Workbook	Shows windows as worksheets in a workbook or as normal windows.
Scenario Manager	Shows or hides the Scenario Manager Window.
Output	Shows or hides the Output Window.
New Text Window...	Opens a new Text output window
New Time Graph Window...	Opens a new Time Related output window
New Space Graph Window...	Opens a new Graph Related output window
Open Network Window	Opens a new Network window

3.2.4 Project menu

The Project menu offers the following commands:

Properties...	Sets the properties of the Project.

3.2.5 Scenario menu

The Scenario menu offers the following commands:

Calculation Settings...	Sets the data controlling the calculation.
Description...	Edits the description of the Scenario.
Properties...	Sets the properties of the Scenario.
Delete	Deletes the Scenario.
Precipitation...	Edits precipitation parameters.
Evaporation...	Edits evaporation parameters.
Wind direction...	Edits wind direction parameters.
Wind velocity...	Edits wind velocity parameters.
Schemes ▶ Level...	Edits all level boundary schemes.
QH...	Edits all QH-relation boundary schemes.
Q-Add...	Edits all Q-Add boundary schemes.
Concentration..	Edits all concentration boundary schemes.
Load...	Edits all load boundary schemes.
Quality model ▶ Edit...	Edits the Quality model.
Compile	Compiles the Quality model.
Initial conditions...	Sets the initial conditions for the Scenario
Parameters...	Sets the parameters for the Quality model.
External Variables...	Sets the external variables.
Structure Control...	Sets the structure control for the Scenario.

3.2.6 Calculation menu

The Calculation menu offers the following commands:

Update All	Updates the calculation.
Write DUFLOW files	Writes *only* the DUFLOW files.
Run DUFLOW model	Runs the DUFLOW model using the DUFLOW files.

3.2.7 Options menu

The Options menu offers the following commands:

Customize...	Configures the DMS-window.
Settings...	Sets the directories for the presentation scripts.

3.2.8 Window menu

The Window menu offers the following commands, which enable you to arrange multiple project windows in the Working space.

Cascade	Arranges windows in an overlapped fashion.
Tile	Arranges windows in non-overlapped tiles.
Arrange Icons	Arranges icons of minimised windows.
Window 1, 2, ...	Activates the specified window.

3.2.9 Help menu

The Help menu offers the following commands, which provide you assistance with DMS.

Help Topics	Provides the topics on which you can get help.
About DMS...	Displays the version number of DMS.

3.3 Toolbars

The Duflow Modelling Studio distinguishes four toolbars. The Standard, Scenario and Window toolbar are displayed across the top of the DMS-window, below the menu bar. The Palette toolbar is displayed next to the working space, default on the right.

To hide or display a toolbar, choose Toolbar from the View menu. To customize a toolbar, choose Customize from the Options menu.

3.3.1 Standard toolbar

The Standard toolbar offers the following commands:

Click	To
	Create a new project.
	Open an existing Project. DMS displays the Open dialog box, where you can locate and open the desired file.
	Save the active Project with its current name; if you have not named the Project, DMS displays the Save As dialog box.

	Undo the last action.
	Cut the selection.
	Copy the selection.
	Paste the selection.
	Print the active document.
	Display the version number of DMS.
	Start the Help tool, the help file will be started automatically after a command is clicked. The description of the chosen topic is shown.
	Modify the scripts for the presentation mode.

3.3.2 Scenario toolbar

The Scenario toolbar offers the following commands:

Click	To
	Edit the properties of the network objects.
	Edit precipitation parameters.
	Edit evaporation parameters.
	Edit wind direction parameters.
	Edit wind velocity parameters.
	Add your comments for the Scenario.
	Calculate the results of the active Scenario.
	Show or hide the Scenario Manager window.
	Show or hide the Output window.

3.3.3 Window toolbar

The Window toolbar offers the following commands:

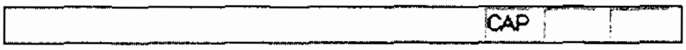
Click	To
	Arrange windows in an overlapped fashion.
	Arrange windows in non-overlapped tiles - horizontally.
	Arrange windows in non-overlapped tiles - vertically.
	Open a Text window.
	Open a Time Related Graph window.
	Open a Space Related Graph window.
	Open a Network window.

3.3.4 Palette toolbar

The Palette toolbar offers the following commands:

Click	To
	Select an object in the network.
	Pan the entire network.
	Show a part of the network in more detail.
	Show a larger part of the network.
	Show the values in the graph at the place of the hairline
	Set the layers of the Network window.
	Show the entire network.
	Add a node to the network.
	Add a section to the network.
	Add a discharge point to the network.
	Add a schematization point to the network.
	Add an area to the network.
	Add a cross-section to the network.
	Add a siphon to the network.
	Add a culvert to the network.
	Add a weir to the network.
	Add a pump to the network.
	Add a general structure to the network.
	Edit the properties of the selected object.
	Remove selected object from the network.
	Set display options of the Network window.
	Set the selection of the network objects

3.4 Status Bar



The Status bar is displayed at the bottom of the DMS window. To display or hide the Status bar, use the Status Bar command in the View menu.

The left area of the Status bar describes actions of menu items as you use the arrow keys to navigate through menus. In a similar way the Status bar shows messages that describe the actions of toolbar buttons as you move across them with the mouse pointer. Release the mouse button while the pointer is off the toolbar button if you do not want to execute the command.

The Status bar displays the position of the cursor in the network, while moving the cursor through the window.

The right areas of the Status bar indicate which of the following keys are latched down:

Indicator	Description
CAP	The Caps Lock key is latched down.
NUM	The Num Lock key is latched down.
SCRL	The Scroll Lock key is latched down.

3.5 Scenario Manager window

The Scenario Manager window displays a project-tree for all opened Projects. To display or hide all the Scenarios of the project click with the left mouse button on the plus- or minus-sign before the Project name. To display or hide the subjects of a Scenario click with the left mouse button on the plus- or minus-sign before the Scenario name.

To display or hide the Scenario Manager window, use the Scenario Manager command in the View menu. To change the font of the Scenario Manager, click on the right mouse button outside the project-tree.

3.6 Working space

The working space can contain the Network window and Result windows of different Project and Scenario's. The Network Editor consists of the Network window and the Palette toolbar.

To open a window use one of the following commands in the View menu or from the window toolbar:

Open Text window

Open Time Related Graph window

Open Space Related Graph window

Open Network window

Clicking the right-mouse button in the Scenario Manager after the selection of a scenario displays a popup menu with the same commands.

To activate a window and bring it to the front use the command Window 1, 2, ... in the Window menu. When the windows are displayed in a workbook it is also possible to activate a window by clicking on its tab. To display or hide a workbook containing all the opened windows use the Workbook command.

3.6.1 Workbook

Use the Workbook command to show windows as worksheets in a workbook or as normal windows.

Command:

Menu: View - Workbook...

3.6.2 Arrange Windows

Use the Cascade Windows command to arrange multiple opened windows in an overlapped fashion.

Command:

Menu: Window - Cascade

Toolbar: 

3.6.3 Tile Windows

Use the Tile Windows command to vertically arrange multiple opened windows in a non-overlapped fashion.

Command:

Menu: Window - Tile

Toolbar: 

To horizontally arrange multiple opened windows in a non-overlapped fashion you can use the following shortcut:

Toolbar: 

3.6.4 Arrange Icons

Use the Arrange Icons command to arrange the icons of minimised windows at the bottom of the main window. If there is an open project window at the bottom of the main window, some or all of the icons may not be visible because they will be underneath the active window.

Command:

Menu: Window - Arrange Icons

3.6.5 Activate Window

DMS displays a list of opened windows at the bottom of the menu. A check mark appears in front of the listed window name of the active window. Choose a window from this list to bring it to the front.

Command:

Menu: Window - Windows 1,2 .....

3.7 Output window

The progress of DMS-actions are displayed in the Output window. When errors occur during these processes the error messages are also shown in this window. Sometimes the error message will give on a clue how to solve the problem that caused the error. To display or hide the Output window, use the Output command.

3.8 DMS commands

In this paragraph all commands that can be used in all parts of DMS will be described.

3.8.1 Undo last action

Use this command to undo the last action. The changes in the Network window will be visible after redrawing the Network window.

Command:

Menu:	Edit - Undo
Toolbar:	
Keys:	CRTL+Z

3.8.2 Cut Selection

Use this command to cut the selection or selected object(s). You can paste this selection or selected object elsewhere by using the Paste command.

Command:

Menu:	Edit - Cut
Toolbar:	
Keys:	CRTL+X

3.8.3 Copy Selection

Use this command to copy the selection or selected object(s). You can paste this selection or selected object elsewhere by using the Paste command.

Command:

Menu:	Edit - Copy
Toolbar:	
Keys:	CRTL+C

3.8.4 Paste Selection

Use this command to paste the cut or copied selection or selected object(s).

Command:

Menu:	Edit - Paste
Toolbar:	
Keys:	CRTL+V

3.8.5 Print

Use this command to print a document. This command presents a Print dialog box.

Command:

Menu: File - Print...

Toolbar: 

Keys: CTRL+P

3.8.6 Print dialog box

In this dialog box one of the following options can be chosen before the printing starts:

Print Range	Specify the pages you want to print. **All** - prints the entire document. **Pages** - prints the pages you specify.
Print Quality	Choose the desired print quality.
Print to File	Prints to a file on the drive you specify instead of routing it directly to a printer. The Project print commands are stored in a file so that you can print from another computer (with the same printer driver) that does not have DMS installed. When you choose the OK button, DMS displays a dialog box for specifying a new filename
Copies	Type the number of copies for printing.
Collate Copies	Organises pages when printing multiple copies. DMS prints a complete copy of the first documents before it begins to print the first page of the second document.
Printer	Select a printer and a printer connection. You can also control default printer settings for the selected printer. See Print Set-up dialog box.

Related topics:

Print

3.8.7 Print Preview

Use this command to display the active view as it would appear when printed. When choosing this command, the main window will be replaced with a Print Preview window in which one or two pages will be displayed in their printed format.

The Print Preview toolbar provides options for viewing either one or two pages at a time; moving back and forth through the document; zooming in and out of pages; and initiating a print job.

Command:

Menu: File - Print Preview

3.8.8 Print Setup

Use this command to select a printer and a printer connection. This command presents a Print Setup dialog box, where you specify the printer and its connection. You can also control default printer settings for the selected printer. All options are printer specific.

Command:

Menu: File - Print Setup

3.8.9 Help Topics

Use this command to display the opening screen of DMS help. From the opening screen you can jump to several DMS help topics.

Once you open Help, you can click the Contents button whenever you want to return to the opening screen.

Command:

Menu: Help - Help Topics

3.8.10 Context Help

Use the Context Help command to obtain help on some portion of DMS. When you choose the Toolbar's Context Help button, the mouse pointer will change to an arrow and question mark. The Help topic will be displayed for the next clicked item.

Command:

Toolbar: 

Keys: SHIFT+F1

3.8.11 About DMS

Use this command to display the Copyright notice and version number of your copy of DMS, in the About DMS dialog box.

Command:

Menu: Help - About DMS...

Toolbar: 

3.8.12 About DMS dialog box

The About DMS dialog box contains the application name and logo, the DMS version number the Copyright statement. This dialog box also contains a link to the homepage of the STOWA.

By clicking on the **Modules...** button DMS will show the Modules dialog box with more detailed information about the installed modules.

Related topics:

About DMS

3.8.13 Exit DMS

Use this command to end the DMS session. You can also use the Close command on the application control menu. DMS prompts you to save projects with unsaved changes.

Command:

Menu:	File - Exit
Mouse:	Click the application's Exit button.
Keys:	ALT+F4

3.9 Customizing DMS

The Duflow Modelling Studio offers many commands and features to change the DMS-window to the preferences of the user.

3.9.1 Display or hide Toolbar

Use the Display or hide Toolbar command to display or hide a certain Toolbar. A check mark appears next to the menu item when one or more Toolbars are displayed.

Command:

Menu:	View - Toolbar

3.9.2 Display or hide Status Bar

Use the Display or hide Status Bar command to display or hide the Status Bar. This bar displays the action to be executed by the selected menu item or pressed toolbar button and the keyboard latch state. A check mark appears next to the menu item when the Status Bar is displayed.

Command:

Menu:	View - Status Bar

3.9.3 Display or hide Scenario Manager

Use the Display or hide Scenario Manager command to display or hide the Scenario Manager Window, which contains the model data and one or more Scenario's.

Command:

Menu:	View - Scenario Manager
Toolbar:	

3.9.4 Display or hide Output

Use the Display or hide Output command to display or hide the Output Window, which contains messages according the progress of the calculation.

Command:

Menu: View - Output

Toolbar: 

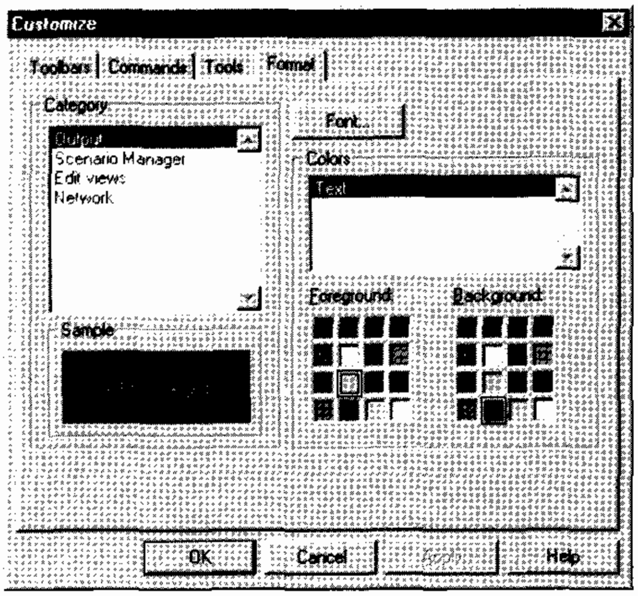
3.9.5 Customize toolbars, menu and windows

Use the Customize command to customize the styles, colors and other features in the DMS windows. DMS will show the Customize dialog box.

Command:

Menu: Options - Customize...

3.9.6 Customize dialog box



The **Toolbar** tab offers the following options:

Toolbars	Shows a list of the available toolbars. To show or hide the toolbar check the specified toolbar in the list.
Toolbar name	Name of the toolbar. Only the name of user-defined toolbars can be changed.
Show Tooltips	By choosing this option a short description of the button will be displayed when the cursor is placed on the button.
Cool Look	Cool looking buttons do not have a border above.
Large Buttons	Use this option to increase the size of the buttons.
New or Delete	Use the New or Delete button to add or remove toolbars. Only user-defined toolbars may be removed.

On the **Command** tab the buttons of the commands belonging to the selected category are displayed. By dragging a button to a toolbar the button is added to the toolbar. By dragging it from the toolbar the button will be removed from the toolbar.

On the **Tools** tab new tool commands my be added to the Edit menu.

The **Format** tab offers options to customize the font and the color for each of the DMS windows.

Related topics:

Customize toolbars, menu and windows

3.9.7 Settings

Use the Settings command to set the Program Settings such as the directories for the Presentation Scripts. DMS will show the Program Settings dialog box.

Command:

Menu: Options - Settings...

3.9.8 Settings dialog box

Related topics:

Settings

3.9.9 Splitter

The DMS-window is divided into the Scenario Manager window, the Working space and the Output window.

The space relation between the three parts is influenced by the Splitter. This is the horizontal or vertical bar between the parts. Moving the mouse above the bar will change the mouse pointer, into a splitter icon. The bar is moved by dragging the splitter icon.

4. Scenario manager

4.1 Usage of the Scenario Manager

The Scenario Manager is there to manage all the data and information needed to run various simulation model scenarios and to store and administrate all scenario's which have been run. The scenario manager facilitates the user in managing different input data within the same project. It also supervises over the integrity of the data and makes it possible to quickly view and compare the results of calculations made with different input parameters.

The scenario manager has three main tasks:

- Facilitation of managing a project. A project consists of in- and output data that belong together. This data is kept in the form of files. A user can frequently alter certain parameters of the input data to view the effects on the calculation results. The scenario manager makes it possible to save an associated set of data together as one scenario.
- Supervision of the integrity of the data within the scenario. When some of the input parameters of a scenario are altered by the user, the data dependent on these parameters, such as the output results, will not contain the correct information. Within DMS, the user will not be able to view this information in the form of tables or graphs unless the information is updated by a new calculation.
- Managing the input parameters when using more than one scenario within the same project. The scenario manager makes it possible to easily combine input parameters from different scenarios. When creating a new scenario, the user may decide to keep some of the input the same the base scenario. On the other hand, it is also possible to define a local copy of the input data for making modifications to the base scenario.

4.1.1 Managing scenarios

Within a project it is possible to define several scenarios. The first scenario created by the user is automatically defined as the base scenario. Scenarios that are created after this base scenario, automatically contain references to the base scenario.

By adjusting the scenario properties, the user can easily combine input data from different scenarios.
The input data is divided into several subjects. For each subject the user can choose to use the data from another scenario (reference) or to define a local copy

and use this data. In the latter case, the data is initially copied from the last scenario, which is referred to as the active scenario.

When using references to other scenarios, the data is shared. Modifying the shared data at one location, means that the data will be changed for all scenarios sharing this data.

The advantage of using references to data from other scenarios is the possibility to change something in, for instance, the network of the base scenario and subsequently calculate the consequences for all scenarios that use the network of the base scenario.

Related topics:

Scenario commands

Scenario Properties

4.2 Project commands

In DMS a DUFLOW model is considered as a Project. To build a model in DMS you have to create a Project.

A Project consists of one or more Scenarios. The first Scenario is the base Scenario. Every Project is stored in its own directory under the project name given by the user. The data of a Scenario is stored in a sub directory of the Project directory under the Scenario name as given by the user.

4.2.1 New Project

Use this command to create a new Project in DMS. DMS will display the New Project dialog box.

Command:

Menu:	File - New...
Mouse menu:	Right mouse button in the Scenario Manager outside the project-tree - New Project...
Toolbar:	
Keys:	CTRL+N

4.2.2 New Project dialog box

In the New Project dialog box you can specify the Project name and first Scenario name you wish to use in the DMS project. All Project data (or reference to data in files) can be stored in a Project File after choosing Save in the File menu.

The selection of the location of the Project directory can be made after clicking the Browse button behind the edit field. The displayed selection dialog is the Browse for Folder dialog box.

You can open an existing Project File with the Open command.

Related topics:

New Project

Open Project

4.2.3 Open Project

Use this command to open an existing Project file. Select the file in the File Open dialog box.

The following options allow you to specify which file to open:

File Name	Type or select the file you want to open. The listbox lists files with the extension you select in the Files of Type combobox.
Files of Type	Select the type of file you want to open. *.DMS is the extension for a Project file.
Look in	Select the drive and directory in which DMS locates the file that you want to open.

You can open multiple projects. Use the Window menu to switch among the multiple open Projects.

You can create a new project with the New command.

Command:

Menu:	File - Open...
Toolbar:	
Keys:	CTRL+O

4.2.4 Close Project

Use this command to close the Project. DMS suggests that you save changes to your files before you closing the Project. Before closing the Project without saving, all changes made since the last save will be lost.

DMS prompts you to save Projects with unsaved changes. Before closing an untitled Project, DMS displays the Save As dialog box and suggests that you name the *.DMS files.

Command:

Menu:	File - Close
Mouse menu:	Right mouse button in the Scenario Manager after the selection of a project - Close

4.2.5 Save Project

Use this command to save the Project (*.DMS) files to its current name and path. When saving the a Project for the first time, DMS will display the Save As dialog box to name the file. When you want to change the name and path of an existing file before saving, choose the Save As command.

Command:

Menu:	File - Save
Mouse menu:	Right mouse button in the Scenario Manager after the selection of a project - Save
Toolbar:	
Keys:	CTRL+S

4.2.6 Save Project As ...

Use this command to save and name the active Project (*.DMS) file. DMS displays the Save As dialog box for naming your files. The following options allow you to specify the name and location of the Project File you are about to save.

File Name	Type a new name to save the Project with a different name. DMS adds the extension specified in the Save as type box (i.e. *.DMS).
Save In	Select the drive and directory in which to store the Project.
Save as type	Select the type of file (depending on the context).

To save files with their existing names and directories, use the Save command.

Command:

Menu: File - Save as...

4.2.7 Import Files

Use this command to import a Project or Project files which were made in the DOS-version of DUFLOW or in RAM 1.0. DMS will show the Open file dialog box.

To import a complete DUFLOW 2.04 or 2.05 project at once select in the Open dialog box the name of the Project (*.PRJ) file. Note that by importing files, all currently defined network objects will be replaced or lost. DMS will prompt you to acknowledge this.

The following file-types are feasible:

DUFLOW Projects File	*.PRJ	File that contains a list of the files needed to run the complete DUFLOW model.
RAM Projects File	*.RAM	File that contains a list of the files needed to run the complete RAM model.
Boundary Conditions Flow File	*.BND	In this file all boundary conditions related to the flow are stored.
Boundary Conditions Quality File	*.BNK	In this file all boundary conditions related to the quality are stored.
Initial Conditions Flow File	*.BEG	In this file all initial conditions related to the flow are stored.
Initial Conditions Quality File	*.BEK	In this file all initial conditions related to the quality are stored.
Control Settings File	*.CTR	File that contains the input data entered in 'Control data'.
External Variables File	*.EXT	In this file all external variables of the quality model are stored.
Node Settings File	*.LAM	Custom RAM settings are stored in this file.
Node File	*.NOD	File that contains the position of nodes in the network.
Network File	*.NET	The nodes are connected through a network. The Network File contains the network, and its geographical dispersion.
Parameters File	*.PRM	In this file all parameters of the quality model are stored.

The displayed selection dialog is the same as the Open dialog box

You can save the old Project as a new Project (*.DMS) file with the Save as command.

Command:

Menu: File - Import...

TIP	Before importing a *PRJ or a *.NOD file make sure that the co-ordinates in the nodes are not equal to zero. If so, all the objects in the Network window will be positioned in one place which makes it impossible to use the commands of the Network window.
TIP	Before importing a project file (*.PRJ) or flow boundary file (*.BND) make sure that if more than one flow boundary condition is defined on one node, every flow boundary condition on that node has its own unique condition number. Otherwise only one flow boundary condition for that node will be converted.

4.2.8 Project Properties

Use this command to set the properties of the project. After selecting this command DMS will show the Project Properties dialog box.

Command:

Menu: Project - Properties...

Mouse menu: Right mouse button in the Scenario Manager window after the selection of a project - Properties...

4.2.9 Project Properties dialog box

In the Projects Properties dialog box it can be specified whether to use a geographical background or not. To define the layers of the geographical background use the Display Layers command.

Related topics:

Project Properties

4.2.10 Recently Opened Projects

Use the numbers and filenames listed at the bottom of the File menu to open one of the last six closed Projects. Choose the Project you wish to open.

Command:

Menu: File - Recently Opened Projects 1,2....

4.3 Scenario commands

A project contains at least one Scenario. When new Scenarios are opened within the same Project the data will be primarily based on this first Scenario.

4.3.1 New Scenario

Use this command to define more than one Scenario in a Project. DMS will show the New Scenario dialog box to specify the name of the Scenario.

Command:

Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a project - New Scenario...

4.3.2 New Scenario dialog box

In the New Scenario dialog box you can specify the name of the new scenario. DMS will create a new scenario directory in the project directory.

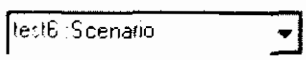
Related topics:

New Scenario

4.3.3 Set as Active Scenario

Use this command to set the selected Scenario as active Scenario. All commands activated thereafter will be executed for this Scenario.

Command:

Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a scenario - Set as Active Scenario
Toolbar:	

4.3.4 Scenario Description

Use this command to add comments about a Scenario. DMS will show the Scenario Description dialog box.

Command:

Menu:	Scenario - Description...
Mouse menu:	Right mouse button in the Scenario Manager window on Description after the selection of a scenario - Edit...
Scen. Manager:	Double-click left mouse button on Description
Toolbar:	

4.3.5 Scenario Description dialog box

In the Scenario Description dialog box you can add comments about the scenario.

Related topics:

Scenario Description

4.3.6 Scenario Properties

Use this command to set the properties of the scenario. After the selection of this command DMS will show the Scenario Properties dialog box

Command:

Menu:	Scenario - Properties...
Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a scenario - Properties...

Related topics:

Scenario Properties dialog box (General)

Scenario Properties dialog box (DUFLOW)

Scenario Properties dialog box (RAM)

4.3.7 Scenario Properties dialog box (General)

The Scenario may contain the input data itself or it may refer to input data of another Scenario. In this dialog box a list of subjects is shown. Each subject refers to certain types of data items, defined by the user. Next to each subject, the user can choose the source of the data to be used for this Scenario. In the subjects the following information about the model is stored:

Schematisation	All data concerning the layout of the network, such as the length of the sections, as calculated by the network editor.
Object data	The properties of all objects defined in the network, such as the cross sectional profiles and the structure properties.
Precipitation	Precipitation data
Evaporation	Evaporation data
QH, Qadd, Level, Concentration and Load	The values of the boundary schemes.
Direction and Velocity	The wind direction and wind velocity information.

By default, DMS will refer to the first created Scenario (the base Scenario) for all subjects. The user can refer to the source of another Scenario by clicking on the arrow at the right side of the list. DMS will show a list of all available Scenario sources. Within this list, there is also the possibility to choose: 'own data'. If this is chosen, the data for the given subject will be stored in this scenario directory instead of another scenario directory. All changes made within the data contained by the subject with 'own data' chosen will now only affect the current scenario. The other Scenarios within the Project will remain unchanged.

Related topics:

Scenario Properties

Scenario Properties dialog box (DUFLOW)

Scenario Properties dialog box (RAM)

4.3.8 Scenario Properties dialog box (DUFLOW)

Each Scenario registers several sets of data. Per set of data one may choose to save the data in the own Scenario directory or receive the data from another Scenario directory. In this dialog box the filenames can be chosen with which the simulation executable (eduflo.exe) performs the calculation.

To refer to data in another directory select the appropriate directory and click on the arrow behind the subject. DMS will show a list with available data files.

This dialog box also contains a list of DUFLOW specific subjects. EXT_VARS contains the information about the external variables. QUALMODEL contains all data concerning the Quality Model and STRUCTCONTROL applies for all data defined by the controlling of structures.

Related topics:

Scenario Properties

Scenario Properties dialog box (General)

Scenario Properties dialog box (RAM)

4.3.9 Scenario Properties dialog box (RAM)

Like in the General tab of the Scenario Properties dialog box this tab shows a list of the RAM specific subject. The user can select the source from which the data is to be derived. UNPAVED refers to the schemes used for the unpaved surface.

Related topics:

Scenario Properties

Scenario Properties dialog box (General)

Scenario Properties dialog box (DUFLOW)

4.3.10 Delete Scenario

Use this command to delete the Scenario. DMS will prompt you to either delete the Scenario directory with all its contents (Yes), delete on only it is contents (No) or do nothing (Cancel).

Command:

Menu:	Scenario - Delete
Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a Scenario - Delete Scenario

4.3.11 Precipitation

Use this command to set or modify the Precipitation time series. DMS will show the Precipitation dialog box. The precipitation scheme is in fact a time series scheme. DMS therefore uses a variation of the Modify Scheme dialog box to modify the precipitation. The unit of precipitation in DMS is mm/day.

Note that for RAM there is a difference in the DMS interpretation of the inserted values. In e.g. a concentration scheme DMS supposes a linear relation between two inserted time steps. For the precipitation in RAM the given values are interpreted as the values "up until now".

For example if entered in the dialog box:

Time	Value
01:00	100
03:00	300

The discharge or concentration at 02:00 is equal to 200, the precipitation at 02:00 is however equal to 300

Command:

Menu:	Scenario - Precipitation...
Mouse menu:	Right mouse button in the Scenario Manager window on Precipitation - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Precipitation.
Toolbar:	

4.3.12 Evaporation

Use this command to set or modify the Evaporation time series. DMS will show the Evaporation dialog box. The evaporation scheme is in fact a time series scheme. DMS therefore uses a variation of the Modify Scheme dialog box to modify the evaporation. The unit of evaporation in DMS is mm/day.

Note that for RAM there is a difference in the DMS interpretation of the inserted values. In e.g. a concentration scheme DMS supposes a linear relation between two inserted time steps. For the evaporation in RAM the given values are interpreted as the values "up until now".

For example if entered in the dialog box:

Time	Value
01:00	100
03:00	300

The discharge or concentration at 02:00 is equal to 200, the evaporation at 02:00 is however equal to 300

Command:

Menu:	Scenario - Evaporation...
Mouse menu:	Right mouse button in the Scenario Manager window on Evaporation - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Evaporation.
Toolbar:	

4.3.13 Wind Direction

Use this command to set or modify the Wind Direction time series. DMS will show the Wind Direction dialog box. The wind direction scheme is in fact a time series scheme. DMS therefore uses a variation of the Modify Scheme dialog box to modify the wind direction. The wind direction is the angle measured clockwise from the North. The unit of the winddirection in DMS is given in degrees (360).

Command:

Menu:	Scenario - Wind Direction...
Mouse menu:	Right mouse button in the Scenario Manager window on Wind Direction - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Wind Direction.
Toolbar:	

4.3.14 Wind Velocity

Use this command to set or modify the Wind Velocity time series. DMS will show the Wind Velocity dialog box. The wind velocity scheme is in fact a time series scheme. DMS therefore uses a variation of the Modify Scheme dialog box to modify the wind velocity. The unit of wind velocity in DMS is m/s.

Command:

Menu:	Scenario - Wind Velocity...
Mouse menu:	Right mouse button in the Scenario Manager window on Wind Velocity - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Wind Velocity.
Toolbar:	

4.3.15 Level Schemes

Use this command to set or modify the Level Schemes. DMS will show the Select Level Scheme dialog box. After the selection of a Level scheme you can set, import or modify Level time series in a variation of the Modify Scheme dialog box. The unit of level in DMS is m (metres).

Command:

Menu:	Scenario - Schemes - Level...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on *Level* (Schemes).

4.3.16 QH Schemes

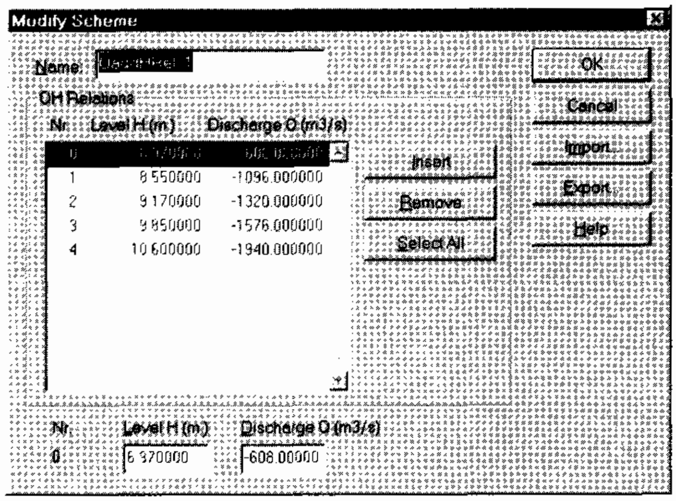
Use this command to set or modify the QH-relation Schemes . DMS will show the Select QH Scheme dialog box. After the selection of a QH scheme you can set, import or modify QH-relation time series in the Modify QH Scheme dialog box. The unit of discharge in DMS is m^3/s, of level is m (metres).

Command:

Menu:	Scenario - Schemes - QH...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on *QH* (Schemes).

4.3.17 Modify QH Scheme dialog box

A Q-H relationship exists of a number of sets including a value for both Level (H) and Discharge (Q). Per Level (H) a specific value for Discharge can be given. The Modify QH Scheme dialog box is used to add or modify these sets. The sets will be sorted by Level automatically.



Modifying the values for Level and Discharge can be done by using the following commands:

Insert	Inserts a new line (set) in the list.
Remove	Removes the highlighted lines from the list.
Select All	Selects all lines in the list so that they can be manipulated together.
Import	Enables you to import a QH-relation from an external ASCII file, saving you the trouble of entering this data manually. The values for Discharge and Level should be separated by a blank, [Tab] or [Return].
Export	Enables you to export a QH-relation to an external ASCII file.

Related topics:

QH Scheme

4.3.18 Q-Add Schemes

Use this command to set or modify the Q-Add Schemes. DMS will show the Select Q-Add Scheme dialog box. After the selection of a Q-Add scheme you can set, import or modify Q-Add time series in a variation of the Modify Scheme dialog box. The unit of discharge in DMS is m^3/s.

Command:

Menu:	Scenario - Schemes - Q-Add...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Q-Add (Schemes).

4.3.19 Concentration Schemes

Use this command to set or modify the Concentration Schemes. DMS will show a variation of the Modify Collection of Schemes dialog box. After the selection of a variable DMS will show the Select Scheme dialog box. After the selection of a Concentration scheme you can set, import or modify Concentration time series in a variation of the Modify Scheme dialog box. DMS uses the following units for the predefined variables, the units of the state variables are defined by the water quality model:

Variable	Unit
Ammonium	mg N/l
Nitrate	mg N/l
Phosphor	mg/l

Command:

Menu:	Scenario - Schemes - Concentration...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Concentration (Schemes).

4.3.20 Load Schemes

Use this command to set or modify the Load Schemes. DMS will show a variation of the Modify Collection of Schemes dialog box. After the selection of a variable DMS will show the Select Scheme dialog box. After the selection of a Load scheme you can set, import or modify Load time-series in a variation of the Modify Scheme dialog box. DMS uses the following units for the predefined variables, the units of the state variables are defined by the water quality model:

Variable	Unit
Ammonium	g N/sec
Nitrate	g N/sec
Phosphor	g/sec

Command:

Menu:	Scenario - Schemes - Load...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Load (Schemes).

4.3.21 Edit Quality Model

Use this command to edit the Quality model. The quality model is a text-file containing the descriptions of the quality processes. The syntax of these descriptions is explained in the Reference Manual. The name of the quality model description file must be specified in the Calculation Settings under the DUFLOW tab. The quality model description file has the extension *.MOD. After creation, it will be stored in the scenario directory.

It is also possible to edit the quality model description file with a different editor like Notepad or Wordpad. The quality model description file should always be saved in text-format.

Command:

Menu:	Scenario - Quality - Edit...
Mouse menu:	Right mouse button in the Scenario Manager window on Quality Model - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Quality Model.

4.3.22 Compile Quality Model

Use this command to compile the Quality model. DUPROL compiles the process descriptions of the *.MOD file and generates a quality model output file which can be read by the DUFLOW calculation process. The name of the quality output file must be specified in the Calculation Settings under the DUFLOW tab. The quality model output file has the extension *. MOB.

Compiling the quality model will not change the values of the parameters or the initial values of the variables.

Command:

Menu:	Scenario - Quality - Compile.
Mouse menu:	Right mouse button in the Scenario Manager window on Quality Model after the selection of a scenario - Compile.

Tip	Before compiling make sure that the quality model is closed with an empty line at the bottom, otherwise DUPROL will not be able to compile the file correctly.

4.3.23 Initial Conditions

Use this command to set or modify the Initial Conditions of all the objects in the active scenario. DMS will show the Initial Conditions dialog box.

It is also possible to start the Initial Conditions command in the Object Properties dialog box on the DUFLOW tab. DMS will show the Initial Conditions dialog box (object oriented) with the initial conditions of the selected object.

When you have completed a DUFLOW calculation you can also re-initialize the Initial Conditions using the New Initial Conditions command.

Command:

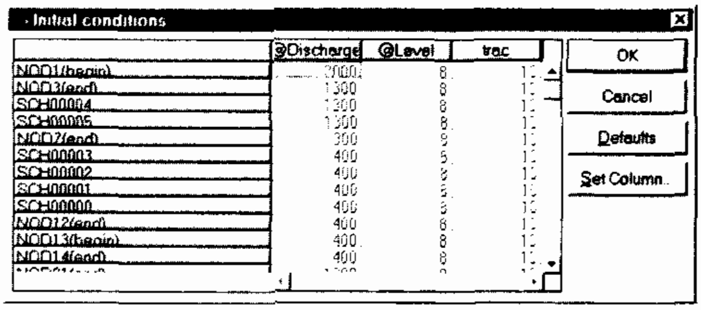
Menu:	Scenario - Initial Conditions...
Mouse menu:	Right mouse button in the Scenario Manager window on Initial Conditions - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Initial Conditions.

Tip	The new initial conditions dialog box can also be used in case of modelling dredging operations. Calculate first your model before dredging, then change the initial conditions and the state variables of the bottom and calculate the dredged situation.

Related topics:

New Initial Conditions

4.3.24 Initial Conditions dialog box



Use the **Set Column...** button to change the initial values for all objects to the same value. DMS will open the Set Column dialog box. Using the **Defaults** button sets the initial values for discharge and level to zero. Quality variables will be set to the default value as defined in the quality model description file.

Related topics:

Initial Conditions

New Initial Conditions

4.3.25 Set Column dialog box

In the Set Column dialog box the initial values for all objects for one column can be changed to the same value. In this dialog box you can select the column of which you want to change the initial values and enter the a new initial value for all objects.

Related topics:

Initial Condition

Initial Conditions dialog box

4.3.26 New Initial Conditions

When you have completed a DUFLOW calculation you can also re-initialize the Initial Conditions using the New Initial Conditions command. DMS will show the New Initial Conditions dialog box.

Command:

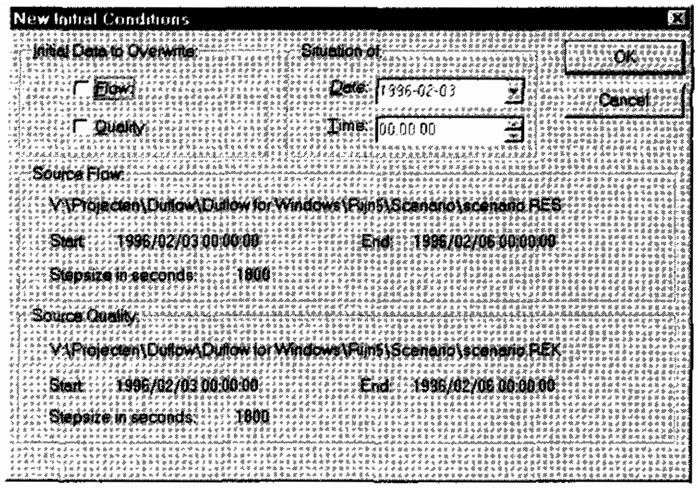
Mouse menu:	Right mouse button in the Scenario Manager window on Initial Conditions - New Initial Conditions...

Related topics:

Initial Conditions

4.3.27 New Initial Conditions dialog box

In the New Initial Conditions dialog box you can specify the data which will be used to re-initialize the Initial Conditions.



The data will be read from the earlier calculation. To re-initialize the initial conditions for flow or for quality mark the appropriate checkbox.

Select a date and time of a stable situation in the earlier calculation. Default DMS will present the start date and time of the earlier calculation, this is never the most stable situation !

Related topics:

New Initial Conditions

4.3.28 Parameters

Use this command to modify the values of the parameters as defined in the quality model description file. The initial values are copied by DMS from the quality model description file. DMS will show the Parameters dialog box.

Command:

Menu:	Scenario - Parameters...
Mouse menu:	Right mouse button in the Scenario Manager window on Parameters - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Parameters.

4.3.29 Parameters dialog box

The Parameters dialog box contains a table of parameters declared in the Quality Model description file. By changing the value of a parameter the Quality Model can be calibrated. Use the **Defaults** button to change the value in the default values. The default values are defined in the Quality Model description file.

Related topics:

Parameters

4.3.30 External Variables

Use this command to set or modify the External Variables schemes. DMS will show a variation of the Modify Collection of Schemes dialog box. After the selection of a External Variable DMS will show the Select Scheme dialog box. After the selection of an External Variable scheme you can set, import or modify External Variable time series in a variation of the Modify Scheme dialog box.

It is also possible to start the External Variables command in the Object Properties dialog box on the DUFLOW tab. DMS will show the External Variables dialog box (object oriented) with the selected schemes for the External Variables of the selected object.

Note that the dispersion coefficient is also considered to be an external variable although it is not declared in the Quality Model description file.

Command:

Menu:	Scenario - External Variables...
Mouse menu:	Right mouse button in the Scenario Manager window on External Variables - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on External Variables - Edit....

You can also an external variable scheme to all objects by using the Connect To All command:

Command:

Scen. Manager:	Double-click left mouse button in the Scenario Manager window on External Variables - Connect to all objects....

4.3.31 Structure Control

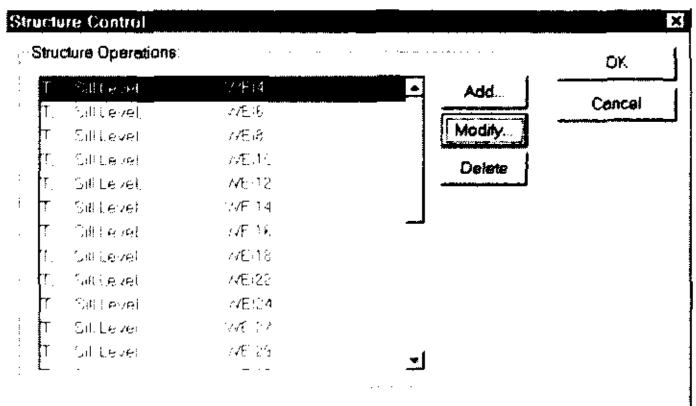
Use this command to set or modify a Structure Operation. DMS will show the Structure Control dialog box. After the selection of a Structure Operation you can set, import or modify Structure Operation time series.

Command:

Menu:	Scenario - Structure Control...
Mouse menu:	Right mouse button in the Scenario Manager window on Structure Control - Edit...
Scen. Manager:	Double-click left mouse button in the Scenario Manager window on Structure Control.

4.3.32 Structure Control dialog box

The Structure Control dialog box contains an overview of the defined Structure Operations.



Use the **Add...** or **Modify...** button to describe a new Structure Operation or to modify one. DMS will open the Structure Operation dialog box.

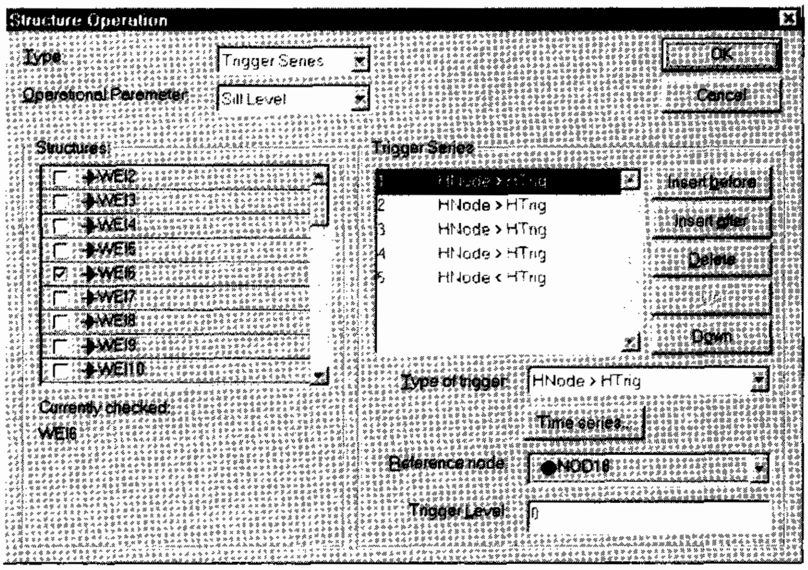
Related topics:

Structure Control

Structure Operation dialog box

4.3.33 Structure Operation dialog box

In the Structure Operation dialog box the specifications of structure operations can be entered.



Defining the structure operations can be done by entering the following individual specifications:

Type of operation	Continuous	The operation will be executed during the entire period of the calculation.
	Trigger series	A 'scenario' that describes the variation of one Parameter in one or more structures depending on actual hydraulic conditions, called Trigger Conditions. A 'scenario' may consists of more than one Trigger series. The number of operations times and the number of structures per operation may not exceed 16. Each 'structure operation' may have up to 99 'trigger conditions'.
Operational parameter	The parameter of the structure that will be affected by this structure operation. Note that earlier parameter values are overwritten.	
Structure	Specify the structure(s). Take care that the Operational Parameter has a meaning for the given structure(s) (e.g. do not change the sill level of a pump).	

Continuous Operations

Continuous Operations can be specified by entering a time series for the specified Operational Parameter.

Trigger Series

Trigger series can be build from individual triggers using the following buttons:

Insert before	Inserts a new trigger before the highlighted line in the list.
Insert after	Inserts a new trigger after the highlighted line in the list.
Delete	Removes the selected trigger from the list.
Up	Moves the selected trigger one position up in list.
Down	Moves the selected trigger one position down in list.

A Trigger itself can be specified by the one of the following Type of Trigger Conditions:

Time	After the specified time has passed the next trigger is checked. If at that moment the new condition is met, it is activated immediately.
H2 > H1 + ΔH	Operational Parameter is executed if the level at the end node is higher than the level at begin node plus an increment ΔH. The value(s) of the Operational Parameter must be specified by a timeseries.
H1 > H2+ ΔH	Operational Parameter is executed if the level at begin node is higher than the level at end node plus an increment ΔH. The value(s) of the Operational Parameter must be specified by a timeseries.
Hnode > Htrig	Operational Parameter is executed if the level at a node somewhere in the network (Trigger node) is higher than a specified level (Trigger level). The value(s) of the Operational Parameter must be specified by a timeseries.
Hnode < Htrig	Operational Parameter is executed if the level at a node somewhere in the network (Trigger node) is lower than a specified level (Trigger level). The value(s) of the Operational Parameter must be specified by a timeseries.
Copy	A Trigger Condition which already has been specified can be repeated by entering its serial number.

The Operational Parameter will change according to the entered time series. The first value will be assigned immediately after the condition is met. The last value will be kept until the next condition is met.
If the next trigger condition is met before the end of this time series then the new condition overrules the old one.

Related topics:

Structure Control

Structure Control dialog box

4.4 Schemes and time series

Much of the data in DMS is stored in schemes. Using schemes makes it easy to add or modify data without overwriting the old data. Schemes can be connected to Network objects. The properties of an object can be changed just by connecting another scheme. It is also possible to change the properties of several objects which use the same scheme by modifying the values of that scheme.

The selection of the connected scheme takes place in the Select Scheme dialog box. After the selection of a scheme it is possible to modify the scheme in the Modify Scheme dialog box. This dialog box will also be shown when a new scheme is added.

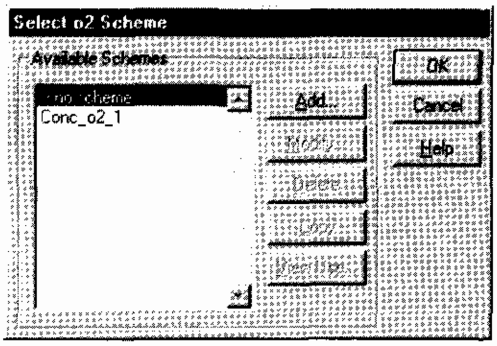
Most schemes contain different kinds of time series. A time series contains a series of values for a time dependent variable or parameter. Time series are inserted by the users or can be imported from an existing ASCII-file.

4.4.1 Modify Collection of Schemes dialog box

After selecting a variable in the Modify Collection of Schemes dialog box and pressing the **Modify**... button DMS will show the Select Scheme dialog box for the selected variable.

4.4.2 Select Scheme dialog box

Properties describing the data are grouped in a scheme. All available schemes are shown in the list in the Select Scheme dialog box.



The following buttons are available in the Select Scheme dialog box:

Add, Modify	Schemes can be added or modified by using the appropriate button. Modify will show the Modify Scheme dialog box with the existing scheme values. Add will show the same dialog box with empty values/fields.
Copy	Copies the selected schemes in the listbox to make small alterations without changing the original. The copied scheme has the same name plus an added number.
Delete	Deletes the selected scheme.
View Use	Opens the Scheme Usage dialog box with an overview of the objects which use the selected scheme.

4.4.3 Scheme Usage dialog box

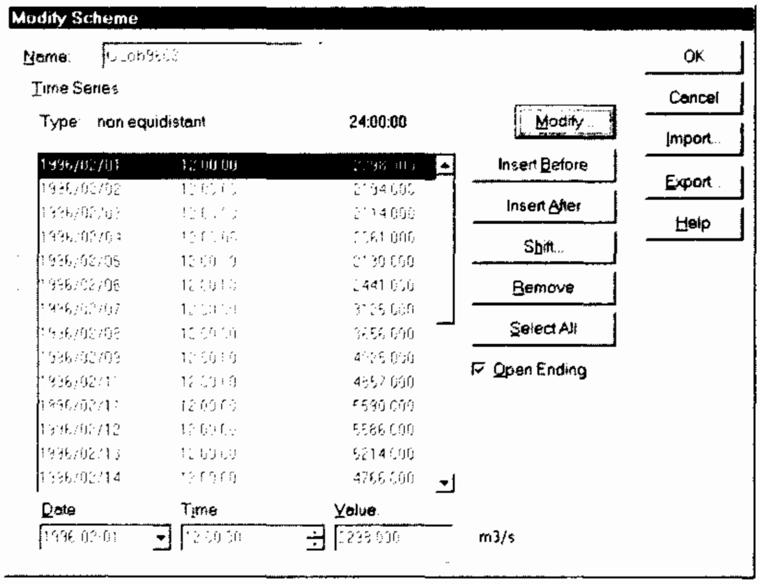
The Scheme Usage dialog box displays an overview of all objects which use the selected scheme.

Related topics:

Select Scheme dialog box

4.4.4 Modify Scheme dialog box (time series)

Many schemes are in fact time series schemes. Per date and time a specific value can be given. The Modify Scheme dialog box is also used to modify time series.



A time series can be constant, equidistant (all values separated by an equal time step), or non-equidistant (the time between values differ). When switching from non-equidistant to equidistant date and time, the value is changed to fit this equidistant requirement. It is also possible to formulate the time scheme as a Fourier series.

The time series options can be set in the Modify Time Series Settings dialog box, after clicking the **Modify...** button.

Modifying the values or the time at which they occur is done using the following command:

Insert before — Inserts a new value based on the step size before the highlighted line in the list.

Insert after — Inserts a new value based on the step size after the highlighted line in the list.

Shift — Shifts the highlighted lines in the list, using the Shift Values dialog box. In this dialog box it is also possible to alter the start date and time of the simulation.
In an equidistant time series the Shift values option can only be used if all values are selected. The series must remain complete, i.e. there must be a value for every time step. Shifting values to another date, and thereby breaking the time chain is not allowed.

Remove — Removes the highlighted lines from the list.

Select All — Selects all lines in the list so that they can be manipulated together.

Open ending — The scheme covers a certain period. In the Model Calculations Settings dialog box) a calculation period is defined. The calculation period may be longer than the period of the scheme.

The open ending option completes the scheme (with the last value of the scheme) to fit to the length of a (longer) calculation scheme.

Import — Enables you to import a time series file from an external ASCII file, saving you the trouble of entering this data manually. The format for the date is jjjj-mm-dd or jjjj/mm/dd, the format for the time is hh:mm:ss.

Two types of data files can be read:

Equidistant time series:
A record of the data file contains only one variable value. The file itself may be of a free format, values can be separated by a blank, [Tab] or [Return]. After importing the file the "Start date", "Start time" and "Interval" must be specified. These items therefore must not be stored in the external file. The default values are equal to the default format in the Model Time Series Settings dialog box.

Non equidistant time series:
A record of the data file must contain date, time and actual value. During the import the data will be written to a DUFLOW input file. When later on, changes are made in the ASCII file, the DUFLOW input file will not be updated.

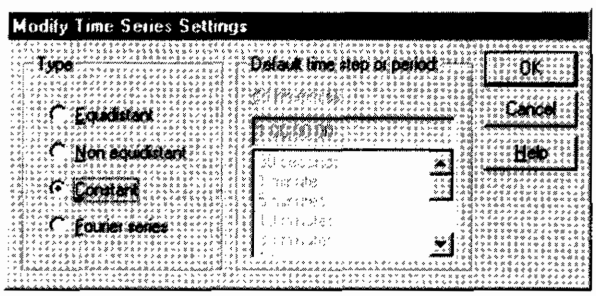
Export Enables you to export a time seriess to an external ASCII file.

Related topics:

Select Scheme dialog box

4.4.5 Modify Time series Settings dialog box

The Modify Time series dialog box enables you to change the properties of a time series.



DMS supports the following possibilities for entering time dependent functions:

Constant
The input variable is constant in time.

Fourier Series
The input variable can be formulated as a Fourier series.

$$y_t = y_0 + \sum_{k=1}^{N} y_k \cos(k\omega t - \Phi_k)$$

$$\omega = \frac{360}{P_1}$$

y_t	Value at time t.
y_0	Mean value.
y_k	Amplitude of k^{th} component.
k	Component number.
N	Number of components.

P Cycle first component.

ω Frequency

t Time

Φ_k Phase of k^{th} component (in degrees).

Equidistant Time series
An equidistant time series which covers the entire simulation period plus one "Time step Quality".

Non-equidistant Time series
A non-equidistant time series needs to cover the entire simulation period. Numerical values should be entered for date, time and actual value. The values used by DUFLOW will be calculated by means of linear interpolation.

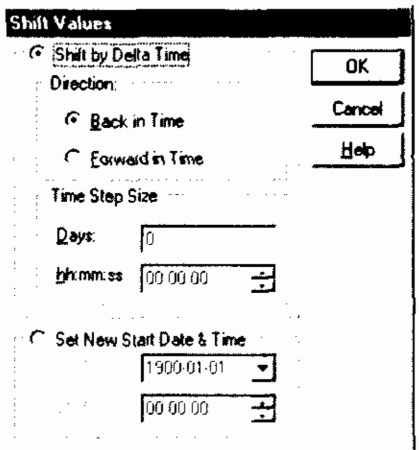
Whenever you change these settings and press OK, DMS will ask you to confirm the conversion.

Related topics:

Modify Time series Settings dialog box

4.4.6 Shift Values dialog box

To shift an existing value to a new date, use this dialog box.



Choose whether the value has to go forward or backward in time, specify the day, hour, minutes and seconds of the shift or set a new start date and time of the time series.

Related topics:

Modify Scheme dialog box

5. Network Editor

5.1 Usage of the Network Editor

The Network Editor is a graphical editor that enables you to interactively draw the network schematization. The desired object (e.g. a node) can easily be selected from the Palette toolbar. The mouse is used to place the object in the network window. This Network Editor is based on the standard exchange format, which has consequences for the way in which the network is set up.

In the standard exchange format, a schematization is built up of nodes and sections.

- Nodes are points at which one or more sections arise or end.
- A section connects two nodes.

The following quantities can be defined on a section:

- Structures
  such as weirs, culverts, siphons, pumps and general structures like underflows.
- Area points
  In area points the drainage from the areas (due to rainfall) and evaporation is taken into account for the surface water.
- Discharge points
  These points take waste loads at the surface water into account.
- Cross-sectional data
  such as resistance coefficients and cross sectional profile.
- Schematization points
  In these points the results of the calculations are recorded. Area and Discharge points are attached on schematization points. On a schematization point one or more areas and discharges may be defined.

The schematization is set up and adjusted by selecting and dragging the objects into the Network window.

In DMS nodes are defined at the beginning and end of a section and in situations where three or more sections meet. A section is defined between two nodes and schematization points and calculation points are defined on the section. If the user wishes to receive output on certain locations on the section schematization points can be placed on the section.

The network is converted to a 'DUFLOW' network by substituting the nodes and schematization and calculation points into DUFLOW nodes and converting the DMS section into several DUFLOW sections. The user can define the distance between two output nodes, which leads to the fact that after conversion of the network, the DMS section is divided into DUFLOW sections of these lengths.

By selecting objects in the Network window, one can activate the Object Properties dialog box, where the properties of these objects can be modified.

Cross-sections can be applied on miscellaneous places on the section. The cross sectional profile over the entire section is default interpolated over the cross-sections inserted by the user. Each section must contain at least one cross sectional profile.

5.1.1 Open Network Window

Use the Open Network Window command to display the network. DMS will open the Network window. To open a Network window a project must be opened.

Command:

Menu:	View - Open Network Window.
Mouse menu:	*Right* mouse button in the Scenario Manager window after the selection of a scenario - Open Network Window.
Toolbar:	.

5.2 Network Objects

The Network window shows the schematization of the waterways. The schematization is built by using Network Editor. A schematization consists of objects. These objects can be dragged from the Palette toolbar into the Network window. The Palette toolbar offers the following objects:

- Node
- Section
- Schematization point
- Discharge point
- Area
- Cross-section
- Siphon
- Culvert
- Weir
- Pump
- *General structure*

Modifying properties of the objects is done in the Object Properties dialog box.

5.2.1 Node

Nodes are points from which one or more sections arise or end.

Symbol: ●

The following properties can be described:

General

ID Identification code of the node.

Name Name of the node.

X-coordinate The X-coordinate of the node is calculated by DMS based, on the position of the node in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS. [m]

Y-coordinate The Y-coordinate of the node is calculated by DMS based on the position of the node in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS. [m]

Boundary Conditions After the selection of the **Boundary Conditions...** button DMS will show the Boundary Conditions dialog box. This dialog box gives an overview of the selected schemes defining the boundary conditions. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the **[...]** button to open the Select Scheme dialog box to add or modify schemes.

Duflow

Initial Conditions After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model.

Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.

External Variables After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the **[...]** button to open the Select Scheme dialog box to add or modify schemes.

RAM

No RAM specific data can be defined.

5.2.2 Section

A section connects two nodes.

Symbol: 

The following properties can be described:

General

ID Identification code of the section.

Name Name of the section.

Length The length of the section is calculated by DMS based on the length of the section in the Network window. By entering a check mark behind the [m] field the user can override the value calculated by DMS.

Duflow

Minimum Length	If the length of the section is shorter than the Minimum length of the section. DMS will consider the length of the section to be equal to zero. In the calculation the begin- and end node of the section will be considered as one node.	[m]
Maximum Length	If the length of the section is longer than the Maximum length of the section. DMS will define Calculation points on the section. The length of the part of the section between two calculation points will never exceed this maximum length. By changing the maximum length, the user can manipulate the space step, Δx, in the calculation. Output is available on calculation points. Calculation points will be visible in the Network window as grey diamonds after the Calculate command is given. The Calculation points will disappear by the Cleanup Network command.	[m]
Interpolate Cross-section data	By choosing this option DMS will interpolate the Cross-sectional data between the Cross-sections, inserted on this section. The Cross-section data of the part of a section between a node and the nearest defined Cross-section is always equal to the data of that Cross-section. If this option is not checked, DMS will consider the Cross-sectional data over a section to be constant until the next inserted Cross-section, when moving in the positive direction of the section. Note that the bottom level is part of the Cross-section data, it will however always be interpolated between two Cross Sections.	
Wind Conversion factor	Wind conversion coefficient * 10^{-6}. Default value is 3.6. Sheltering from the wind by dikes, buildings etc. can be simulated by specifying a lower value.	[-]
Generate Output data	Choosing this option will generate output for this section. By default this option will be checked.	
Add to Monitoring file	Choosing this option will write the output for this section to the Monitoring-file. The Monitoring file has the extension *.MON.	

RAM

No RAM specific data can be defined.

5.2.3 Schematization point

Schematization points are extra points on a section used by the DMS calculation and on which output can be generated. On a schematization point one or more areas and discharge points may be defined.

Symbol: ○

The following properties can be described:

General

ID	Identification code of the schematization point
Name	Name of the schematization point

Section ID — ID of the section on which the schematization point is defined.

X-coordinate — The X-coordinate of the schematization point is calculated by DMS, based on the position of the schematization point in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS. [m]

Y-coordinate — The Y-coordinate of the schematization point is calculated by DMS, based on the position of the schematization point in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS. [m]

Distance — The distance from the begin node of the section until the schematization point is calculated by DMS, based on the positions of the node and the schematization point in the Network window. By entering a check mark behind the field the user can override the value of DMS. [m]

DUFLOW

Initial Conditions — After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model.

Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.

External Variables — After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the [...] button to open the Select Scheme dialog box to add or modify schemes.

RAM

No RAM specific data can be defined

5.2.4 Discharge point

On Discharge points discharge in or out of the Network or waste loads at the surface water into the Network can be taken into account. Discharge points must always be attached to a Schematization point It is possible to attach more than one Discharge point to the same Schematization point.

Symbol 

The following properties can be described:

General

ID — Identification code of the Discharge point

Name — Name of the Discharge point

Schematization point ID — ID of the Schematization point on which the discharge point is attached. At this Schematization point the discharge into the network will be taken into account.

Boundary Conditions	After the selection of the **Boundary Conditions** button DMS will show the Boundary Conditions dialog box. This dialog box gives an overview of the selected schemes which contain the boundary conditions. By clicking on the arrow behind the scheme-name list with the available schemes will be displayed. Use the **[...]** button to open the select Scheme dialog box to add or modify schemes.
Duflow	No Duflow specific data can be defined
RAM	No RAM specific data can be defined

5.2.5 Area

In Area points the drainage from the areas into the surface water.(due to rainfall) is taken into account. Areas must always be attached to a Schematization point. It is possible to attach more than one Area to the same Schematization point.

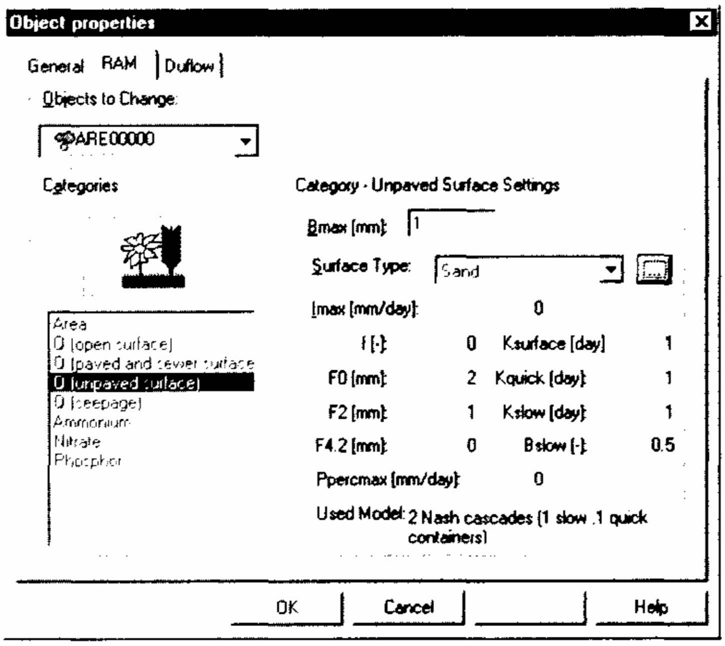
Symbol: 

The following properties can be described:

General

ID	Identification code of the object	
Name	Name of the object	
Schematization point	ID of the schematization point on which the area is attached. At this schematization point the discharge of the area into the network is taken into account.	
Surface	Total surface of the area.	$[m^2]$
RAM	See description below	
Duflow	No Duflow specific data can be defined	

The RAM specific properties are displayed as follows:



The following categories of properties are modifiable, the properties (and the dialog) change when a new category is selected:

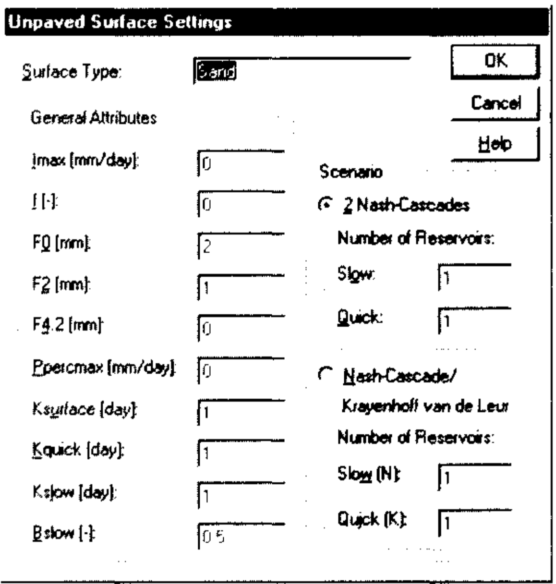
Icon	Category	Properties	
	**Area**	Total area	Precipitation collection area. [ha]
		% Open	Percentage of the total area that consists of surface water. [-]
		% Paved	Percentage consisting of (fast spouting) paved surface. [-]
		% Unpaved	Percentage of the area used as farmland (the precipitation is flowing away slowly). [-]
		% Sewer	Sewer, used in the calculations. [-]
	**Open surface**	k	Time constant, reservoir separated sewer system [day]
		f	Crop factor Makkink [-]
	**Paved surface**	ks	Time constant, reservoir separated sewer system [day]
		kp	Time constant reservoir paved surface [day]

Note: For the crop factor Makkink (f) the open surface value is also used for paved surface.

Icon	Category	Properties	
	**Unpaved surface**	Bmax	Maximum storage in surface depressions. [mm]
		Surface type	Surface Type and its contents are set in the Select Unpaved Surface Scheme dialog box
	**Seepage**	C	Vertical hydraulic resistance of covering layer. [day]
		DH	Hydraulic head difference covering layer and water transporting package. [m]
	**Ammonium**	Concentration schemes for: Open Water Paved Surface Unpaved Surface (Open) Unpaved Surface (Slow) Unpaved Surface (Fast) Seepage	
	**Nitrate**	Concentration schemes for: Open Water Paved Surface Unpaved Surface (Open) Unpaved Surface (Slow) Unpaved Surface (Fast) Seepage	
		N	Nitrate concentration
	**Phosphor**	Concentration schemes for: Open Water Paved Surface Unpaved Surface (Open) Unpaved Surface (Slow) Unpaved Surface (Fast) Seepage.	

Concentration schemes are selected in the Select Concentration Scheme dialog box which is a variation of the Modify Scheme dialog box.

Properties describing the unpaved surface are grouped in an Unpaved Surface scheme. The schemes facilitate the use of predefined data and the use of schemes from other projects. After selecting an Unpaved Surface scheme DMS will show the Unpaved Surface settings dialog box.



In the Unpaved surface dialog box the following parameters can be described:

Heading	Properties	Explanation
Surface Type		Scheme name.
General Attributes	Imax	Infiltration capacity. [mm/day]
	f	Cropfactor Makkink. [-]
	F0	Moisture storage at pF = 0. [mm]
	F2	Moisture storage at pF = 2. [mm]
	F4.2	Moisture storage at pF = 4.2. [mm]
	Ppercmax	Percolation to saturated zone between pF = 0 en pF = 2 (maximum). [mm/day]
	Ksurface	Time constant reservoir unpaved surface [day]
	Kfast	Time constant fast groundwater discharge. [day]
	Kslow	Time constant slow groundwater discharge. [day]
	B	Distribution formula fast and slow groundwater discharge. [-]
Scenario	Select the Nash-cascade or the Krayenhoff vd Leur scenario and the number of reservoirs to represent the discharge.	

Properties describing the concentration are grouped in a Concentration scheme which is in fact a time series scheme. DMS therefore uses a variation of the Modify Scheme dialog box.

5.2.6 Cross-section

Cross sections contain Cross-sectional data such as resistance coefficients and cross sectional profiles. Cross-sections must be defined on a section.

Symbol: 

The following properties can be described:

General

ID	Identification code of the Cross-section.	
Name	Name of the Cross-section	
Section ID	ID of the section on which the cross-section is defined.	
X-coordinate	The X-coordinate of the cross-section is calculated by DMS, based on the position of the cross-section in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Y-coordinate	The Y-coordinate of the cross-section is calculated by DMS, based on the position of the cross-section in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Distance	The distance from the begin node of the section until the Cross-section is calculated by DMS, based on the positions of the begin node and the Cross-section in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Scheme	Name of the Cross-section scheme. See below	

Duflow

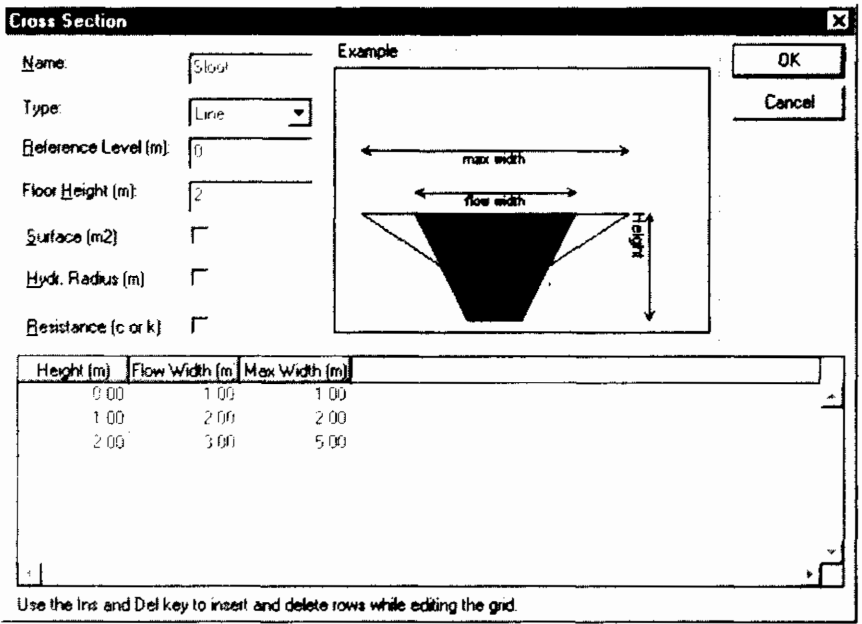
Resistance positive direction	If in the Calculation Settings De Chézy as Resistance Formula is specified, the value is equal to the Chézy-coefficient in positive direction (from begin node to end node). If Manning is specified, the value is equal to the coefficient K in the formula of Manning ($v=K*R^{2/3}*I^{1/2}$) in positive direction.	$[m^{1/2}/s]$ or $[m^{2/3}/s]$ (K)
Resistance negative direction	If in the Calculation Settings De Chézy as Resistance Formula is specified, the value is equal to the Chézy-coefficient in negative direction (from end node to begin node). If Manning is specified, the value is equal to the coefficient K in the formula of Manning ($v=K*R^{2/3}*I^{1/2}$) in negative direction.	$[m^{1/2}/s]$ or $[m^{2/3}/s]$ (K)

RAM

No RAM specific data can be defined

Properties describing the Cross-section are grouped in a Cross-section scheme. The schemes facilitate the use of predefined data and the use of schemes from other scenarios. After selecting a Cross-section scheme DMS will show the Cross-section dialog box.

5.2.7 Cross Section dialog box



In the Cross-section dialog box the following properties can be described:

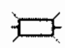
General

Name	Name of Cross-section scheme	
Type	Type of Cross-section: Line, Circle or Trapezoid.	
Reference Level	Reference level only used for defining the Floor Height of the Cross Section. Default: '0'	[m]
Floor Height	Height of the lowest point of the Cross-section with respect to the reference level as inserted above.	[m]
Radius (Circle)	Length of the radius of a circular Cross-section.	[m]
Bottom Width (Trapezoid)	Width of the bottom.	[m]
Slope Angle (Trapezoid)	Angle between the slope and the horizontal plane.	[degrees]
Surface (Line)	Option to overrule the implicitly calculated Flow Profile Area (A) by the values entered in the Surface column. This option makes it possible to define the Flow Profile Area as a function of the depth.	[m^2]
Hydraulic Radius (Line)	Option to overrule the implicitly calculated Hydraulic Radius(R) by the values entered in the Hydraulic Radius column. This option makes it possible to define the Hydraulic Radius as a function of the depth.	[m]
Resistance (Line)	Option to overrule the value for the Resistance of the Section by the values entered in the Resistance column. This option makes it possible to define the Resistance as a function of the depth and place on the section. If in the Calculation Settings De Chézy as Resistance Formula is specified, the value is equal to the Chézy-coefficient. If Manning is specified, the value is equal to the coefficient K in the formula of Manning ($v=K*R^{2/3}*I^{1/2}$).	[$m^{1/2}/s$] or [$m^{1/3}/s$]

	The value for the Resistance can be inserted for the positive and negative direction of the section.	
Height (Line)	Depth to Floor Height (bottom) on which the parameters are valid.	[m]
Flow Width (Line)	Width of Flow Profile at the related height.	[m]
Maximum Width (Line)	Width of Storage Profile at the related height.	[m]

5.2.8 Siphon

A Siphon is circular pipe used to carry water over obstacles.

Symbol: 

The following properties can be described:

General

ID	Identification code of the Siphon.	
Name	Name of the Siphon.	
Section ID	ID of the section on which the siphon is defined.	
Distance	The distance from the begin node of the section until the siphon is calculated by DMS, based on the position of the node and the siphon in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Tube Width	The width of the tube of the siphon.	[m]
Tube Height	The height of the tube of the siphon.	[m]
Tube Length	The length of the siphon.	[m]
Side Resistance	The Chézy coefficient for the friction in the siphon. The friction in the siphon is always calculated with the formula of De Chézy.	$[m^{1/2}/s]$

Duflow

Start Level and Stop Level	Switching levels above the reference level. The flow in the siphon starts if both levels at begin and end are above the Start Level and stops if one of them drops below the Stop Level. The direction from the begin to the end of a siphon corresponds to the direction of the section.	[m]
Mu	Mu is a correction factor for additional hydraulic effects like contraction, internal friction etc. and can be defined at the begin and the end of the siphon in positive and negative direction.	[-]
Initial Conditions	After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model. Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.	
External Variables	After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the	

scheme-name a list with the available schemes will be displayed. Use the [...] button to open the Select Scheme dialog box to add or modify schemes.

RAM No RAM specific data can be defined.

5.2.9 Culvert

A Culvert is a pipe-construction with a rectangular or circular cross-section which connects two waterways.

Symbol: 

The following properties can be described:

General

ID	Identification code of the Culvert.	
Name	Name of the Culvert.	
Section ID	ID of the section on which the culvert is defined.	
Distance	The distance from the begin node of the section until the culvert is calculated by DMS, based on the positions of the node and the culvert in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Tube Form	Form of the cross-section of the tube: Rectangular or Round.	
Tube Width	The width of the tube of the culvert.	[m]
Tube Height	The height of the tube of the culvert above the sill level.	[m]
Tube Length	The length of the culvert.	[m]
Side Resistance	The Chézy coefficient for the friction in the culvert. The friction in the culvert is always calculated with the formula of De Chézy.	[$m^{1/2}$/s]
Sill Level	The level of the bottom of the flow opening above the reference level. The part of the culvert below the sill level is not a part of the flow profile of the culvert.	[m]
Inside Level	The level of the lowest point of the elliptic cross-section.	[m]

Duflow

Mu Free Surface	Mu is a correction factor for additional hydraulic effects like contraction, internal friction etc. in the culvert and can be defined in positive and negative direction.	[-]
Mu Submerged	Mu for submerged flow situations in the culvert and can be defined in positive and negative direction.	[-]
Initial Conditions	After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model. Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared	

in the Quality Model description file.

External Variables

After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the [...] button to open the Select Scheme dialog box to add or modify schemes.

5.2.10 Weir

A Weir is a construction made to control the level on the upstream side with a free watersurface.

Symbol: 

The following properties can be described:

General

ID

Identification code of the Weir.

Name

Name of the Weir.

Section ID

ID of the section on which the Weir is defined.

Distance

The distance from the begin node of the section until the weir is calculated by DMS, based on the positions of the node and the weir in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS. [m]

Crown Width

The width of flow opening of the weir. [m]

Crown Height

The height of the bottom of the flow opening above the reference level. [m]

Mu

Mu is a correction factor for additional hydraulic effects like contraction, internal friction etc. in the weir and can be defined in positive and negative direction. [-]

Duflow

Initial Conditions

After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model.

Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.

External Variables

After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the [...] button to open the Select Scheme dialog box to add or modify schemes.

RAM No RAM specific data can be defined

5.2.11 Pump

Pump stands for a pumping station in or near a waterway.

Symbol: 

The following properties can be described:

General

ID	Identification code of the Pump.	
Name	Name of the Pump.	
Section ID	ID of the section on which the Pump is defined.	
Distance	The distance from the begin node of the section until the siphon is calculated by DMS, based on the positions of the node and the siphon in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Capacity	Discharge through the pumping station when the pump is on.	$[m^3/s]$
Start Level and Stop Level	Switching levels above the reference level. The Start and stop levels are related to the level at the begin node. If the start level is higher than the stop level the pumping station can pump the water from begin node to the end node, otherwise the water can be pumped from the end node to the begin node. If the start level is higher than the stop level the pump starts when the upstream level reaches above the start level and stops when the upstream level drops below the stop level. If the start level is lower than the stop level the pump starts when the upstream level drops below the start level and stops when the upstream level reaches above the stop level.	[m]

Duflow

Initial Conditions	After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model. Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.
External Variables	After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the **[...]** button to open the Select Scheme dialog box to add or modify schemes.

RAM No RAM specific data can be defined

5.2.12 General Structure

General Structures are structures which can not be defined as other DMS-structures, for example weirs with forced underflow.

Symbol: 

The following properties can be described:

General

ID	Identification code of the General Structure.	
Name	Name of the General Structure.	
Section ID	ID of the section on which the General Structure is defined.	
Distance	The distance from the begin node of the section until the general structure is calculated by DMS, based on the positions of the node and the general structure in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Width Whirlpool	The width of flow opening of the general structure.	[m]
Height Whirlpool	The height of the flow opening of the general structure.	[m]
Gate Level	The level of the upper side of the flow opening of the general structure above the reference level.	[m]
Mu Free Surface	Mu is a correction factor for additional hydraulic effects like contraction, internal friction etc. in the general structure and can be defined in positive and negative direction.	[-]
Mu Submerged	Mu for submerged flow situations in the general structure and can be defined in positive and negative direction.	[-]

Duflow

Initial Conditions

After the selection of the **Initial Conditions...** button DMS will show the Initial Conditions dialog box with the initial conditions for discharge, level and all state variables declared in the Quality model.

Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.

External Variables

After the selection of the **External Variables...** button DMS will show the External Variables dialog box. This dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality model. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the **[...]** button to open the *Select Scheme dialog box to add or modify* schemes.

RAM No RAM specific data can be defined

5.3 Network window commands

5.3.1 Display Layers

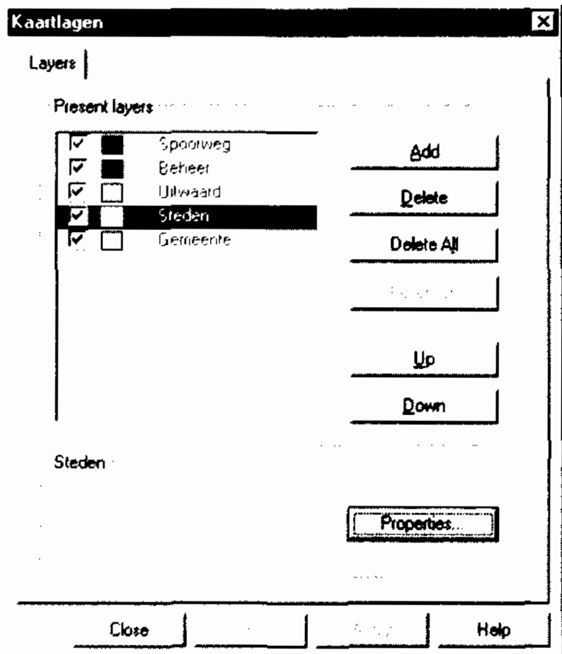
Use the Display Layers command to add or remove layers in the Network window. DMS will show the Display Layers dialog box dialog box. This command can only be used when in the Project Properties dialog box the setting Geographic Background is marked.

Command:

Toolbar: 

5.3.2 Display Layers dialog box

The Display Layers dialog box contains a list with the present layers. The order of the layers in this list correspond with the order in which the layers are displayed in the Network window. To modify this order select a layer and use the **Up** or **Down** button.



Use the **Add** button to add layers to the Network window. DMS will open the Open File dialog box. Only Shape-files can be used as a layer in DMS. Select the file in the File Open dialog box.

The following options in the Open File dialog box allow you to specify which file to open:

File Name — Type or select the file you want to open. The listbox lists files with the extension you select in the Files of Type combobox.

Files of Type — Select the type of file you want to open:

*.SHP is the extension for a Shape file.

*.VSF is the extension for a collection of Shape-files.

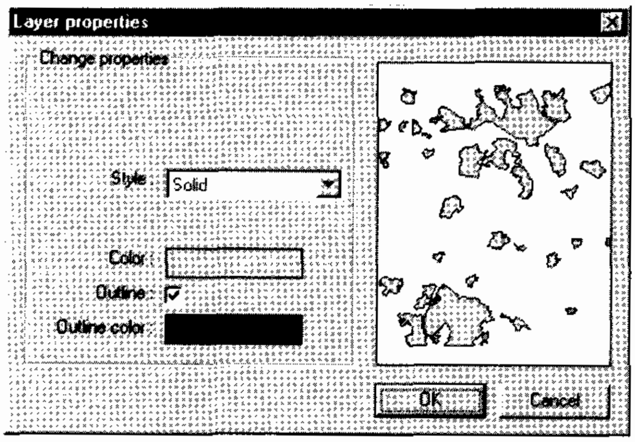
Look in — Select the drive and directory in which DMS locates the file that you want to open.

When a Shape-file is selected, DMS will show the Color dialog box to choose the right color for the selected layer. Use the Properties button on the Layers dialog box to change the color or style of the layer. DMS will show the Layer Properties dialog box.

Related topics:

Display layers

5.3.3 Layers Properties dialog box



The following options in the Layers Properties dialog box allow you to specify the properties of the layer:

Size	Thickness of the lines.
Style	Style in which the layer is drawn.
Color	Color of the lines or the filling colors of the objects in the layer.
Outline	Option to choose whether the objects of the layer should have an outline or not.
Outline Color	Color of the outline of the objects in the layer.

By removing the mark in the row of a present layer the layer will temporarily not be displayed. Use the **Delete** or **Delete All** button to remove the layer(s) from the list.

A set of layers can be saved as *.VSF file by choosing the button **Collection**. To use this button more than one layers must be selected in the Display Layers dialog box by using the **CRTL** or **SHIFT** button

Related topics:

Display Layers dialog box

5.3.4 Object Properties

Use this command to edit properties of the objects. After selecting this command, DMS displays the Object Properties dialog box.

If one or more objects in the Network window are selected when using the toolbar shortcut for this command, you can only edit the properties of the selected object.

Command:

Menu: Edit - Objects - Properties...

Mouse menu: Right mouse button in the Network window after the selection of an object - Properties...

Toolbar: (lists all objects of active scenario)

(lists only the selected object)

5.3.5 Object Properties dialog box

The Object Properties dialog box consists of three parts. The general data, RAM specific data and the DUFLOW specific data. After the selection of the object(s) to change on the *General* tab you can change the properties of the object(s). More information about the properties of the object is given in the paragraph about that object.

Related topics:

Node

Section

Schematization point

Discharge point

Area

Cross-section

Siphon

Culvert

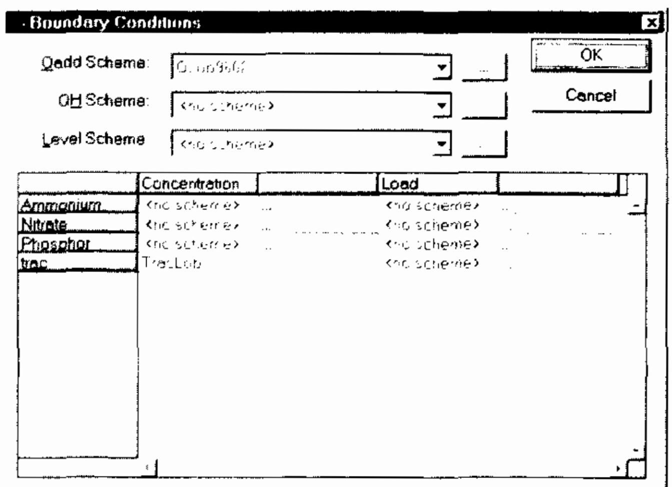
Weir

Pump

General Structure

5.3.6 Boundary Conditions dialog box (object oriented)

The Boundary Conditions dialog box gives an overview of the selected schemes which contain the boundary conditions.



By clicking on the arrow behind the scheme-name list with the available schemes will be displayed. Use the [...] button to open the Select Scheme dialog box to add or modify schemes.

Boundary Conditions only can be defined for nodes and discharge points. Boundary Conditions for level or a Q-H relation can not be defined on a discharge point.

If RAM is installed, the table with the Quality Boundary Conditions always contains the quality variables Ammonium, Nitrate and Phosphor. These quality variables are predefined in RAM.

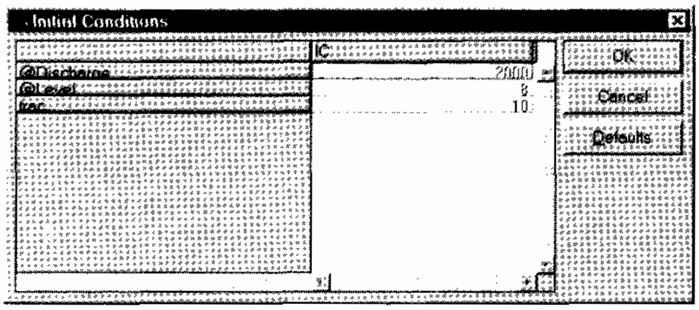
Related topics:

Node

Discharge point

5.3.7 Initial Conditions dialog box (object oriented)

The Initial Conditions dialog box contains an overview with the initial conditions for discharge, level and all state variables declared in the Quality Model description file for the selected object.



Use the **Defaults** button to set the value of discharge and flow equal to zero and the value of the state variables to the default values declared in the Quality Model description file.

Related topics:

Initial conditions

5.3.8 External Variables dialog box (object oriented)

The External Variables dialog box gives an overview of the selected schemes for the dispersion and the other external variables declared in the Quality Model description file. By clicking on the arrow behind the scheme-name a list with the available schemes will be displayed. Use the [...] button to open the Select Scheme dialog box to add or modify schemes.

Related topics:

External Variables

5.3.9 Check Objects

Use this command to check objects. The selection is made in the Check Objects dialog box.

Checked objects are used to display graphs, in the Object Properties dialog box and for generating the logfile.

Objects can also be checked with mouse actions in the Network window.

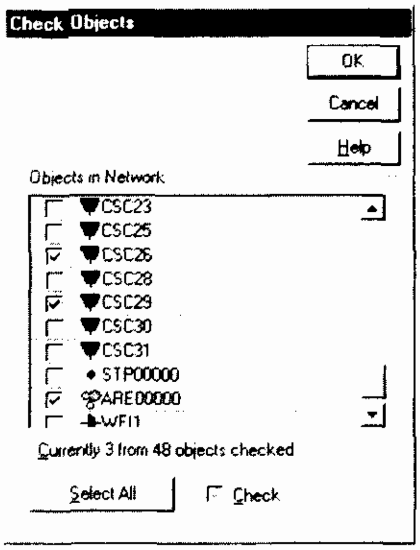
Command:

Menu: Edit - Objects - Select...

Toolbar: 

5.3.10 Check Objects dialog box

The Check Objects dialog box allows you to specify the checked objects.



All objects are listed, the checkbox before each object tells you whether the object is checked. The state of an object can be changed by directly clicking the objects checkbox in the listbox.

The **Select All** button makes it possible to make a choice for all objects, by using the Ctrl or Shift button or by dragging the mouse other multiple selection can be made. The **Check** checkbox shows the state of the selected objects:

- checked means all selected objects are checked
- *grey means that some* of the selected objects are checked
- unchecked means that none of the selected objects are checked.

You can also use the **Check** checkbox to change the state of the selected objects.

Related topics:

Check Objects

5.3.11 Select Object

Use this command to select an object from the network.

Command:

Mouse menu: Right mouse button outside the network objects - Selection mode

Toolbar: 

5.3.12 Show Object Types

Use this command to show or hide objects types. In the Network window. The selection is made in the Show Network Objects dialog box.

Command:

Mouse menu: Right mouse button outside the network objects - Show Object Types

5.3.13 Show Network Objects dialog box

The Show Network Objects dialog box allows you to specify Object Types to be displayed in the Network Window.

All object types are listed, the checkbox before each object tells you whether the object is checked. The state of a object can be changed by directly clicking the objects checkbox in the listbox.

Related topics:

Show Object Types

5.3.14 Cleanup Network

Use the Cleanup Network command to remove the calculation points or to make changes visible after using the Undo command.

Command:

Mouse menu: Right mouse button in the Network window - Cleanup Network

5.3.15 Flip Orientation

Use the Flip Orientation command to change the direction of a section.

Command:

Mouse menu: Right mouse button in the Network window after the selection of a section - Flip Orientation

5.3.16 Bending Point

Use the Bending Point command to mark a schematization point into a bending point. To create a bending in the network select the bending point and drag it to the desired position.

Command:

Mouse menu: Right mouse button in the Network window after the selection of a schematization point - Bending Point

5.3.17 Remove Object

Use this command to remove an object from the network.

Command:

Mouse menu: Right mouse button after selecting an object - Remove object

Toolbar: 

Keys: DEL (after selecting an object)

Related topics:

Remove Node and Join Sections

5.3.18 Disconnect Object

Use the Disconnect Object command to disconnect a object from the network. This command is not available for nodes and sections.

Command:

Mouse menu: Right mouse button in the Network window after the selection of an object - Disconnect Object

5.3.19 Remove Node and Join Sections

Use the Remove Node and Join Sections command to remove a node from the network and join the sections which begin or end at the removed node. This command can only be used when two sections come together at the selected node.

Command:

Mouse menu: Right mouse button in the Network window after the selection of a node - Remove node and Join Sections

5.3.20 Insert Node

Use the Insert Node command to add a node in a section of an existing network. The section will be split into two sections which inherit the properties of the splitted section.

Command:

Mouse menu: Right mouse button in the Network window after the selection of a section - Insert Node

5.3.21 Offset Coordinates

Use the Offset Coordinates command to change the X- and Y-coordinates from all objects at once. DMS will show the Offset dialog box to specify values - negative or positive - to add to the current coordinates.

Command:

Mouse menu: Right mouse button in the Network window outside the network objects - Special - Offset...

5.4 Moving through the Network window

5.4.1 Entire Network

Use the Entire Network command to show the entire network in the Network window.

Command:

Mouse menu: Right mouse button in the Network window outside the network objects - Auto adjust limits

Toolbar: 

5.4.2 Zooming Tool

Use the Zooming Tool to show parts of the network in more detail. After selecting the command (from the menu or the toolbar) the cursor will change into a magnifying glass. Dragging the cursor displays a rectangle on your screen. This rectangle represents the area that will be magnified (the rectangle will be blown up until it fills the network window).

Command:

Mouse menu: Right mouse button in the Network window outside the network objects or in the Graph window - Zoom mode

Toolbar: 

5.4.3 Zooming out

Zooming is usually done in stages, more and more detail of the network or graph is displayed. Zooming out lets you retrace these stages. Zoom out works independent from the zooming tool (the zooming tool does not have to be selected to zoom out).

To zoom out to the unzoomed state in the Network window, use in the Entire network command.

Command:

Mouse menu: Right mouse button in the Network window outside the network objects or in the Graph window - Zoom out

Toolbar: 

5.4.4 Pan network

Use this command pan the network and move it through the Network window. To move the network drag the cursor (a hand) through to the Network window.

Command:

Mouse menu: Right mouse button outside the network objects - Pan mode

Toolbar: 

5.4.5 Current Position

Use the Current Position command to show or set the X- and Y-coordinate of the bottom-left corner of the Network window. DMS will show the Current View Position dialog box. The Current Position dialog box also shows the current zoom factor.

When moving the cursor through the Network window the position of the cursor is displayed in the Status bar.

Command:

Mouse menu: Right mouse button in the Network window outside the network objects - Special - Current Position...

5.4.6 Locate Object

Use the Locate Object command to find an object in the Network window by giving the object ID. DMS will show the Locate Object dialog box. When an object-id is entered, the specified object will blink in the Network window. The search-function is not case-sensitive.

It is also possible to search for object numbers in the DUFLOW files. The object which corresponds to the number in the DUFLOW files can be found in the Network window just entering that number preceded by a 'n' in case of a Node or a 's' in case of a Section/Structure.

Command:

Mouse menu:	Right mouse button in the Network window - Locate Object...

5.4.7 Locate Object dialog box

To find an object in the Network window enter the complete object ID of the searched object and click OK. If the specified object is found, it will blink in the Network window. The search-function is not case-sensitive.

To find an object in the Network window by the object number from the DUFLOW files, enter the number preceded by a 'n' in case of a Node or a 's' in case of a Section/Structure.

5.5 Customizing Network window

5.5.1 Window Properties (Network window)

Use the Window Properties command to edit the drawing properties of the Network window.. DMS will open the Drawing Properties dialog box.

The Drawing Properties dialog box offers the following options:

Pointsize Objects	Pointsize of the objects in the Network Window. Default value is 10.
Show Text	Choose this option to display the ID's of all objects in the Network window.
Show Data Tips	Choose this option to display the object ID in the Network window when the cursor is placed above that object. On Cross sections a small picture of the cross-section will also be displayed.
Editable	Choose this option to allow or prohibit changes in the Network.

Command:

Menu:	Edit - Window Properties...
Mouse menu:	Right mouse button outside the network objects in the Network window - Special - Drawing properties.
Toolbar:	

5.5.2 Presentation Mode

Use this command to select a Presentation Script for the network window. With a Presentation Script one can define the attributes of the Network objects - such as color and style - as a function of the output-values. DMS will open the Select Presentation Script Scheme dialog box. After the selection of a Presentation Script, DMS will redraw the network dialog box according to the presentation script. In the Network window a date-field and arrow-buttons are available to move through the calculation period in time.

Use this command after a calculation is made.

Command:

Menu:	Edit - Presentation Mode
Mouse menu:	Right mouse button in the Network window - Presentation mode

Related topics:

Presentation Scripts

Presentation Scripts dialog box

Settings dialog box

5.5.3 Presentation Scripts

Use this command to modify the Presentation Scripts. DMS will open the Select Presentation Script Scheme dialog box to add, modify, delete or copy a Presentation Scheme. To add or modify a Presentation Script scheme DMS will open the Presentation Scripts dialog box.

Command:

Menu:	Edit - Presentation Scripts...
Toolbar:	

5.5.4 Presentation Script dialog box

In the Presentation Script dialog box you can to specify the presentation script by the following properties:

Name	Name of the presentation script.
Object Type	Listbox presenting all types of Network objects. After the selection of an object type a presentation script for that type of object can be written. The available attributes of the selected type of object can be presented with the **Attributes** button.
Script	Text window to edit the script for the selected object. Use the **Syntax Check** button to check the syntax of the script. The syntax is described in the Reference Manual.

Related topics:

Presentation Scripts

Available Attributes dialog box

Settings dialog box

5.5.6 Editable

Use this command to allow or prohibit changes in the Network.

Command:

Menu:	Edit - Editable
Mouse menu:	Right mouse button outside the network objects in the Network window - Special / Drawing properties - Editable

6. Calculation

6.1 Calculation commands

The output of a calculation of DMS strongly depends on the options that are chosen in the Calculation Settings dialog box.

The calculation is divided into three steps. First the RAM calculation is performed. Next the input data of the Network window is written to the so-called DUFLOW files. These DUFLOW files contain ASCII text. The format of these files are described in the Reference Manual. Finally the calculation is performed and the results are stored in the results files (*.RES contains the flow results, *.REK contains the quality results)

The above steps are performed sequentially by giving the Calculate command but also can be performed separately by first giving the Write DUFLOW Files and finally the Run DUFLOW Model command.

The output for flow of a RAM calculation is always a discharge on the Area points. These additional discharges can be used as Boundary Conditions in a DUFLOW calculation. When performing a DUFLOW calculation together with a RAM calculation the RAM calculation is performed first and DMS will automatically use the generated boundary conditions from RAM for the DUFLOW calculation.

Tip	To use the output for Ammonium, Nitrate and Phosphor from the RAM calculation as a boundary in the DUFLOW calculation, declare these state variables with exactly the same name in the Quality model.

6.1.1 Calculation settings

Use this command to set or modify the settings that govern the calculation. DMS will show the Calculation Settings dialog box. The Model Calculations Settings dialog box consists of three parts. The general settings, defining the computational duration and time steps. The **RAM** part, for definitions of the RAM calculation. The **DUFLOW** part, for defining the quality model, De Chezy values, Theta values etc..

Command:

Menu:	Scenario - Calculation Settings...
Mouse menu:	Double-click left mouse button in the Scenario Manager window on Calculation settings after the selection of a scenario.

Right mouse button in the Scenario Manager window on Calculation settings after the selection of a scenario - Edit

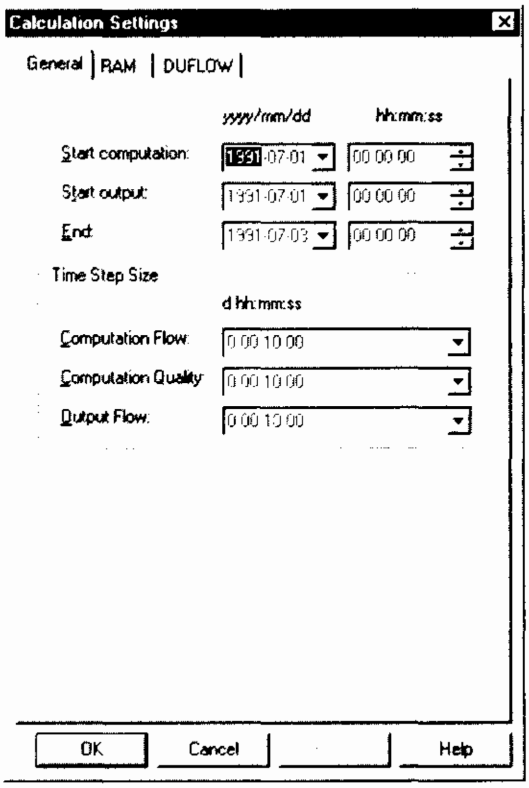
Related topics:

Calculations Settings dialog box (general)

Calculations Settings dialog box (RAM)

Calculations Settings dialog box (DUFLOW)

6.1.2 Calculations Settings dialog box (general)



The **General** calculation settings are subject to the following conditions:

Start computation
Set the start date and time for the calculation.

Start output
Set the start date and time of writing data to the result file. This enables the user to skip output of the first part of the simulation. This can be convenient if the initial conditions do not represent the physical state of the system at the start of the simulation.

End
Set the end date and time for the calculation.

Time Step size, Computation Flow
Time interval used for calculation in the hydraulic part. The Reference Manual gives suggestions for the choice of the hydraulic time step.

Time Step size, Computation Quality
Time interval for the quality part of the model. The Reference Manual gives suggestions for the choice of the quality time step. The Quality time step is rounded to the nearest multiple of the Flow time step.

Time Step size, Output — Set the output time step, the output time step must be a multiple of the *calculation time step*.

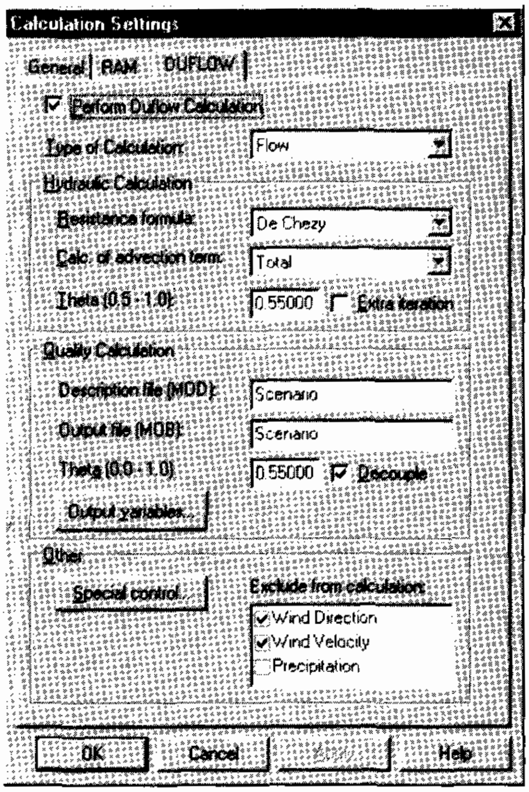
Related topics:

Calculation Settings

Calculations Settings dialog box (RAM)

Calculations Settings dialog box (DUFLOW)

6.1.3 Calculations Settings dialog box (DUFLOW)



The DUFLOW calculation settings are subject to the following conditions:

Perform DUFLOW Calculation — Checkbox to choose whether a DUFLOW calculation should be made or not when giving the Calculate command.

It is also possible to perform only a RAM calculation.

Type of Calculation

Flow
Only flow is calculated

Flow and Quality
Flow and quality are calculated simultaneously

Quality
This option can only be used if an intermediate flow result file (*.DMP) was generated in a flow calculation. In this case the necessary flow information for the mass transport is read from the intermediate flow result file. This option can be useful if different quality calculations have to be performed all using the same flow calculations. This is the case if one or more parameters of the water quality model are changed during the calibration of the model, or if another process description file is

used to generate another water quality model.

Box
Using this option only the processes as defined in the process description file will be simulated. Transport is not calculated. The calculations will be performed for all defined sections within the network. Boundary conditions (both Flow and Quality) will not be used. If in the process description file flow variables are used, the default values from the *.MOD file will be used. External variables (time dependent and location specific) will be used as defined in the quality menu "external variables". This option is useful when developing and testing a process description file. Furthermore the use of this option enables the examination of the relative importance of the transport processes in comparison with the other processes involved.

Resistance formula

The channel friction can be calculated using:

- the formula of De Chézy. The "resistance" coefficient C in the definition of the sections is from the basic formula: $v = C \cdot \sqrt{R \cdot I}$
- the formula of Manning. The "resistance" is the Manning coefficient k (1/n) from the basic formula $v = k \cdot R^{2/3} \cdot I^{1/2}$. In the actual calculation $C = k \cdot R^{1/6}$ is substituted in the formula of De Chézy.

The value of C is calculated for each time step during the simulation.
Default: De Chézy

More information about the Resistance formula is described in the Reference Manual.

Calc. of advection term.

Option "Total" includes the so-called Froude term. Selecting "Damped" the Froude term is also taken into account, but its absolute value will not exceed the friction term. One may also choose to neglect the entire Froude term with "Neglected Froude".

More information about advection is described in the Reference Manual.

Theta (0.5-1.0)

The factor controlling numerical damping.
Default: 0.55

More information about Theta is described in the Reference Manual

Extra iteration

At each time step the level dependent parameters (like flow area, storage area and hydraulic radius) are calculated from the simulation at the previous time. These values can be adjusted using the 'new' values computed for the actual time using an extra iteration.

Description file

Name of the ASCII-file which containing the quality model. Enter the name of the file without the extension. The file itself must have the extension *.MOD and be located in the sub directory of the scenario. When a non-existing filename is given, DMS will create that file after it has been edited.

To edit the quality model file use the Edit Quality Model command.

Output file

Name of the ASCII-file which contains the compiled quality model. The name of the file must have the extension *.MOB and be located in the sub directory of the scenario. When a non-existing filename is given, DMS will create that file after it has been compiled.

To compile the quality model file use the Compile Quality Model command.

Theta (0.0-1.0)

The factor controlling the numerical solution of the advection and dispersion equation. The value zero ($\theta=0$) is not allowed for numerical reasons.
Default: 0.55

Decouple

If this box is not checked, dispersion is considered at both sides of a node. When checked, only dispersion in forward direction is taken into account. Decoupling only takes place at those nodes, where a discharge is located.

Output Variables

Use this button to select variables for output. DMS will show the Output Variables dialog box. From the displayed checklist state variables and intermediate results defined as function identifiers in the Quality Model file can be selected for output.

Special Control

Use this button to choose other special options like the threshold value for the dry flood procedure. DMS will show the Special Control dialog box.

Exclude from calculation

Use this option to exclude wind velocity, wind direction or precipitation from the calculation.

This option enables the user to get information about the influence of the weather elements on the model.

If the boundary conditions of the DUFLOW model are based on a RAM calculation the effect of precipitation is already taken into account in the RAM calculation. The precipitation should then be excluded from the DUFLOW calculation.

Related topics:

Calculation Settings

Calculations Settings dialog box (general)

Calculations Settings dialog box (RAM)

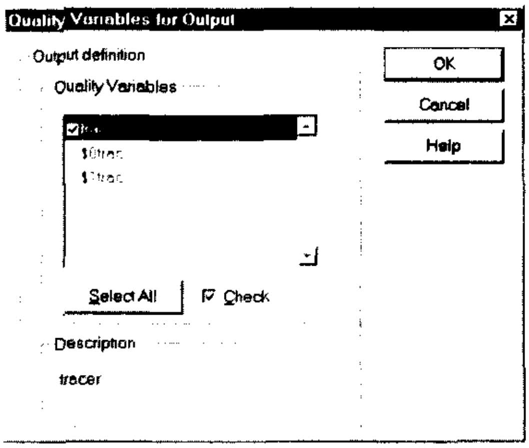
Output Variables dialog box

Special Control dialog box

6.1.4 Output Variables dialog box

From the displayed checklist state variables and intermediate results defined as coefficients and function identifiers in the Quality Model file can be selected for output.

To check al the listed variables use the **Select All** button and mark the 'Check' checkbox field.



The combination '$0' before the variable means the zero order coefficient of that variable, '$1' means the first order coefficient.

Related topics:

Calculation Settings

Calculations Settings dialog box (DUFLOW)

6.1.5 Special Control dialog box

The Special Control dialog box offers the following options:

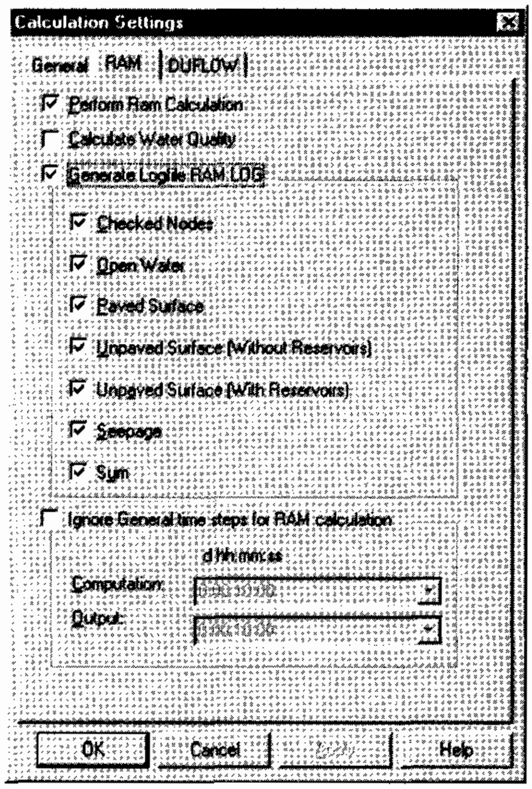
Create intermediate flow file	A dump file will be generated during simulation using option Flow. The intermediate flow result file (*.DMP) will be used to simulate transport if a quality calculation is performed. In this *.DMP file information about volumes, flows etc. is stored, which is read during quality simulation. This enables the user to perform a number of quality simulations using the same hydraulic conditions. Default: No Note that the intermediate flow-files can use a lot of disk space.
Alpha (corr. for velocity distribution)	Represents the influence of the velocity distribution over the cross-section. Default: 1
Minimum # of time steps between triggers	After a trigger condition is affected some shocks can occur due to a sudden change in the structure operation. To prevent the next trigger from reacting to these shocks, the check for this next trigger is omitted during a specified number of time steps. Default: 3
Treshold Level	If the water level reaches below this given level, the dry-flood procedure will be activated. The threshold level is given relative to the bottom level. More information about the dry flood procedure is described in the Reference Manual. Default: 0.10 metre

Related topics:

Calculation Settings

Calculations Settings dialog box (DUFLOW)

6.1.6 Calculations Settings dialog box (RAM)



The RAM calculation settings are subject to the following conditions:

Perform RAM Calculation
Checkbox to choose whether a RAM calculation should be made or not when giving the Calculate command.

It is also possible to perform only a RAM calculation.

Calculate Water Quality
ram always calculates precipitation runoff, an additional choice is calculating the loads or water quality of Ammonium, Nitrate and Phosphor).

Generate Logfile RAM.LOG
The steps in the calculation can be stored in a RAM.LOG file for calculation checks.

The following options enable the user to specify the options used for generating the logfile:

Checked nodes
Include data on checked nodes only. This option is preferred because it reduces the size of the logfile significantly.

Open water
Include data concerning open water.

Paved surface
Include data concerning paved surface.

Unpaved surface (without reservoirs)
Include data concerning unpaved surface without reservoirs.

Unpaved surface (with reservoirs)
Include data concerning unpaved surface with reservoirs.

Seepage
Include data concerning seepage.

Sum
Include the sum of all surfaces.

Ignore general timesteps for RAM calculation	By choosing this option the time step on the tab General will be ignored in the RAM calculation. The time step specified for the RAM calculation can be much larger than the time step which the DUFLOW flow-model requires for a stable calculation.

Related topics:

Calculation Settings

Calculations Settings dialog box (general)

Calculations Settings dialog box (DUFLOW)

6.1.7 Update All

Use this command to update the calculation of the active scenario. DMS will display the progress of the calculation in the Output window. The status of the calculation is visible in the Status Bar.

If in the Output window a message refers to a node, section or structure with a certain number, use the Locate Object command to find the - ID of the - object in the Network.

Command:

Menu:	Calculation - Update All
Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a scenario - Calculate
Toolbar:	

Tip The calculation can be stopped by first opening the CDUFLOW window - which displays the progress of the calculation - and then pressing CTRL-C.

6.1.8 Write DUFLOW files

Use this command to write DUFLOW files without running the model. DMS will show the progress of the writing in the Output window.

DUFLOW files can be read by the executable Cduflow.exe. Cduflow.exe performs the DUFLOW calculation. The DUFLOW-files are stored in the scenario directory.

The following DUFLOW file-types can be distinguished:

Boundary Conditions Flow File	*.BND	In this file all boundary conditions related to the flow are stored.
Boundary Conditions Quality File	*.BNK	In this file all boundary conditions related to the quality are stored.
Initial Conditions Flow File	*.BEG	In this file all initial conditions related to the flow are stored.
Initial Conditions Quality File	*.BEK	In this file all initial conditions related to the quality are stored.
Control Settings File	*.CTR	File that contains the input data entered in 'Control data'.
External Variables File	*.EXT	In this file all external variables of the quality model are stored.

Node File	*.NOD	File that contains the position of nodes in the network.
Network File	*.NET	The nodes are connected through a network. The Network File contains the network, and its geographical dispersion.
Parameters File	*.PRM	In this file all parameters of the quality model are stored.

For more detail information about the DUFLOW files see the Reference Manual.

If in the Output window a message refers to a node, section or structure with a certain number, use the Locate Object command to find the - ID of the - object in the Network.

Command:

Menu: Calculation - Write DUFLOW Files

6.1.9 Run DUFLOW Model

Use this command to run the model based on the DUFLOW files in the scenario directory. By using this command the changes made in the scenario which are not written to DUFLOW files - by using the Update all command or the Write DUFLOW files command - will not be taken into account.

DMS will display the progress of the calculation in the Status Bar below the Scenario Manager window.

Command:

Menu: Calculation - Run DUFLOW Model

6.1.10 Convert Network

Use this command to convert the DMS Network into a network which can be written to the DUFLOW files. By using this command DMS will show the calculation points on the Network window. Calculation points are generated on sections which - by using the Update all command or the Write DUFLOW files command - will not be taken into account.

Redraw the Network, e.g. with the Cleanup Network command, to remove the calculation points from the network.

Command:

Menu: Calculation - Convert Network

Related topics:

Write DUFLOW files

7. Results

7.1 Presentation of the Results

The results of a calculation can be displayed in three different ways:

- A Time Related Graph,
- A Space Related Graph or
- Results as Text in a table as a function of time.

Both text and graphs are displayed in windows. These windows appear in the working space. A result window can contain the output of more than one variable or the output from different scenarios.

By opening more than one result window the results can be interpreted by comparing the different windows.

7.2 Text Window

In a text window the data is displayed in a numerical way and can be written to an external file. By using cut and paste the text can easily be used in other applications.

7.2.1 New Text Window

Use the New Text Window command to display the results of the calculation as text. DMS will open the Time Related Graph dialog box.

Command:

Menu:	View - New Text Window...
Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a scenario - New Text Window...
Toolbar:	

7.2.2 Save Results

Use the Save Results command to save the results that are displayed in the Text window. The Results will be stored in an ASCII-file. DMS will open the Save As dialog box so that you can name your files. The following options allow you to specify the name and location of the Project File you are about to save.

File Name	Type a new name to save the results.
Save In	Select the drive and directory in which you want to store the Text-file.

Save as type	Select the type of file you want to open (depending on the context)

Command:

Mouse menu:	Right mouse button in the Text window - Save...

7.2.3 Change Font

Use the Change Font command to change the font of the Text window. DMS will open the Font dialog box so you change the type, size and style of the font.

Command:

Mouse menu:	Right mouse button in the Text window - Font...

7.3 Graph Windows

7.3.1 New Time Graph Window

Use the New *Time Graph* Window *command* to display the results of the calculation as a function of time. DMS will open the Time Related Graph dialog box.

Command:

Menu:	View - New Time Graph Window...
Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a scenario - New Time Graph Window...
Toolbar:	

7.3.1.1 Display Time Graph per section

To display a time related graph only for one section:

Command:

Mouse menu:	Right mouse button in the Network window after the selection of a section - DUFLOW - New Time Graph Window...

7.3.1.2 Add Time Graph to current graph

To add a time related graph of a section to an already opened time related graph window:

Command:

Mouse menu:	Right mouse button in the Network window after the selection of a section - DUFLOW - Add To Time Graph Window...

It is also possible to alter the graphs, colors or properties to the currently opened graph window:

Command:

Mouse menu:	Right mouse button in the Graph window - Graphs..., Colors... or Properties...

7.3.2 Time Related Graph dialog box.

The Time Related Graph dialog box makes it possible to define what is displayed in the graph window. The Time Related Graph dialog box consist of three parts.

The tab General contains the general data including the boundary conditions, the tabs DUFLOW and RAM contain more specific data.

Choices that can be made are:

Graph Properties	DMS will open the Graph Properties dialog box.
Source	The source of the graph is one of the scenarios which is available in the project. It is possible to display graphs of more than one scenario in one graph window. By using the **...** button you can open a Flow Results file (*.RES) or Quality Results file (*.REK) to display the these results in the same graph. DMS will open the Measured Data dialog box.
Show Precipitation	Shows the precipitation time series in the graph.
Show Evaporation	Shows the evaporation time series in the graph.
Attributes	By making a selection in the Attributes list the available Data Types will be displayed in Show Data checkboxes. Use **Show Data** to select of the selected nodes in the **Objects to Display** list, the kind of graph to show.
Objects to display	Select in the combobox which objects are to be displayed in the adjoined list. Graphs of the selected objects are to be displayed in the Graph window. The **Select All** button makes it possible to select all objects in the list. Use the **CTRL** or **SHIFT** button to make a multiple selection in the list.
Show Data of Type	Use **Show Data** to select of the selected nodes in the **Nodes to Change** list, the kind of graph to show. After a selection is made a picture representing the data type is displayed in the row(s) of the selected objects. Selection of the data type to be displayed in the graphs is also possible by clicking with the left mouse button on the left side of the row(s) of the objects list. The position in the row correspond with the order of the data types list.

Related topics:

New Time Graph Window

7.3.3 New Space Graph Window

Use the New Space Graph Window command to display the results of the calculation as a function of space. DMS will open the Space Related Graph dialog box.

Command:

Menu:	View - New Space Graph Window...
Mouse menu:	Right mouse button in the Scenario Manager window after the selection of a scenario - New Space Graph Window...
Toolbar:	

TIP	To move quickly in time trough a Space Related Graph, place the cursor on a part of the date/time field below the Graph, then use the Up en Down button on the keyboard to move forwards or backwards in time. The step size in time depends on the part of the time-field and the Output time step.

7.3.4 Space Related Graph dialog box

The Space Related Graph dialog box makes it possible to define what is displayed in the graph window. In the Space Related Graph only DUFLOW specific data can be displayed.

Choices that can be made are:

Graph Properties DMS will open the Graph Properties dialog box. For more information see the Window Properties (Graph window) command.

Source The source of the graph is one of the scenarios which is available in the project. It is possible to display graphs of more than one scenario in one graph window.

Attributes By making a selection in the Attributes list the available Data Types will be displayed in Show Data checkboxes. Use **Show Data** to select of the selected nodes in the **Objects to Display** list, the kind of graph to show.

Routes to display Graphs of the selected routes are to be displayed in the Graph window. The **Select All** button makes it possible to select all routes. Use the **CTRL** or **SHIFT** button to make a multiple selection in the list.

Output routes can be defined using the **Define...** button. DMS will show the Select Route Scheme dialog box. Using the **Add...** or **Modify...** button in the Select Route Scheme dialog box DMS will open the Modify Route dialog box to add or modify a route.

Show Graphs of Type Use **Show Graphs of Type** to select of the selected routes in the **Routes to Select** list, the kind of graph to show. After a selection is made a picture representing the data type is displayed in the row(s) of the selected routes.

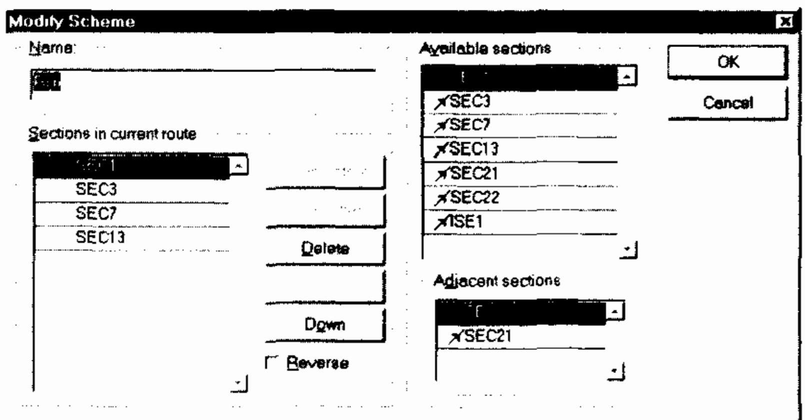
Selection of the data type to be displayed graphs is also possible by clicking with the left mouse button on the left side of the row(s) with the routes. The position in the row correspond with the order of the graph types list.

Related topics:

New Space Graph Window

7.3.5 Modify Route dialog box

In the Modify Route dialog box you can define the route to be displayed on the X-axis in the Space Related graph.



A route consists of the sections in the 'Sections in current route' list. The following commands or options are available to modify this list.

Insert before	Inserts the selected section from the 'Available sections'-list before the highlighted section in the 'Sections in current Route'.
Insert after	Inserts the selected section from the 'Available sections'-list after the highlighted section in the 'Sections in current Route'.
Delete	Removes the selected section from the 'Sections in current Route' list.
Up	Moves the selected section one position up in 'Sections in current Route' list.
Down	Moves the selected section one position down in 'Sections in current Route' list.
Reverse	If the checkbox is marked the section will be presented in the reverse direction on the X-axis of the Space Graph window.

TIP	By double clicking on a section in the 'Available sections' list, the selected section will be inserted in the 'Sections of current route' list after the highlighted section. Using this trick makes it very easy to build a route.

Related topics:

Space Related Graph dialog box

7.4 Graph window commands

7.4.1 Hairline mode

Use the Hairline command to show the exact values in the graph where the hairline is placed. After selecting the command (from the mouse-menu or the toolbar) the cursor will change into a double arrow. Dragging the cursor displays a vertical hairline in your graph. These values of the Y-axis where the hairline crosses the graphs are displayed in the legend.

Command:

Mouse menu: Right mouse button in the Graph window - Hairline mode

Toolbar: 

7.4.2 Zooming Tool

Use the Zooming Tool to show parts of the graph in more detail. After selecting the command (from the menu or the toolbar) the cursor will change into a magnifying glass. Dragging the cursor displays a rectangle on your screen. This rectangle represents the area that will be magnified (the rectangle will be blown up until it fills the graph window).

Command:

Mouse menu: Right mouse button in the Graph window - Zoom mode

Toolbar: 

7.4.3 Zooming out

Zooming is usually done in stages, more and more detail of the graph is displayed. Zooming out lets you retrace these stages. Zoom out works independent from the zooming tool (the zooming tool does not have to be selected to zoom out).

To zoom out to the unzoomed state in the Graph window, use in the Zooming Tool command.

Command:

Mouse menu:	Right mouse button in the Graph window - Zoom out
Toolbar:	

7.4.4 Window Properties (Graph window)

Use the Window Properties command to edit the graph properties of the Graph window. DMS will open the Graph Properties dialog box.

The Graph Properties dialog box offers the following options:

X-Axis	If this option is chosen the default range of the X-axis can be changed.
Y-Axis (left or right)	If this option is chosen the default range of the Y-axis (left or right) can be changed. Use this option in a Space Graph window to fix the range of the Y-axis during all time steps.
Domains	To change the unit of the Y axis select a domain from the list and choose the adjoined Y-axis.
Colors	DMS will open the Colors Graph Window dialog box.

Command:

Menu:	Edit - Window Properties...
Mouse menu:	Right mouse button in the Graph window - Properties...
Toolbar:	

7.4.5 Graphs

Use this command to reset the display options per node, and per source. After selecting the command DMS will show the Display Graphs dialog box. The options in the Display Graphs dialog box are explained in the New Time Graph command or New Space Graph command.

Command:

Menu:	Edit - Graphs...
Mouse menu:	Right mouse button in the Graphs window - Graphs...

Related topics:

Time Related Graph dialog box

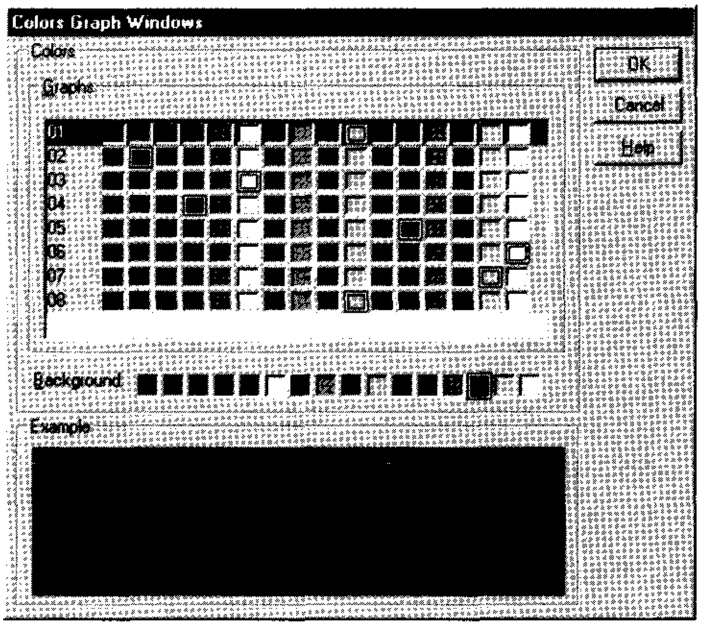
Space Related Graph dialog box

7.4.6 Colors

Use the Colors command to change the colors in the graph window. DMS will show the Colors Graph Window dialog box.

7.4.7 Colors Graph Window dialog box

The color of the lines in the graph window can be customized, using the Colors Graph Window dialog box.



The possible options are:

Graphs — A color can be selected for each line in the graph. The lines are listed in the graphs list box.
To select a color click a colorbox that lies on the same line as the line number. An example for the chosen line is shown in the **Example** groupbox..

Background — Select the background color for the graph dialog box.

Example — Shows the selected line color for the active line in the **Graphs** listbox.

Command:

Menu: Edit - Colors...

Mouse menu: Right mouse button in the Graphs window - Colors...

Related topics:

Colors

8. Glossary of Terms

Area

Schematization-point in which the drainage from the area - due to precipitation - is taken into account for the surface water

Boundary Conditions

Values for Flow and Quality variables defined by the user at the physical boundaries of the network and on hydraulic structures required to start a DUFLOW computation.

Cross-section

Cross-sections contain cross-sectional data such as cross-sectional profiles and resistance coefficients. Cross-sections must be defined on a section.

Culvert

A pipe-construction with a rectangular or circular cross-section which connects two waterways.

Discharge point

Schematization point on which additional discharge into or out of the network are taken into account.

DMS

Abbreviation for Duflow Modelling Studio which manages the Scenario Manager and the Network Editor to perform DUFLOW and RAM calculations. DMS supplies the water authorities with a complete set of tools, to quickly perform easy analysis, on the other hand, the product can also perform complex, integral studies.

DUFLOW

Program with which one can perform unsteady flow computations in networks of open water courses and can simulate the transportation of substances in free surface flow and more complex water quality processes.

DUPROL

Part of the DUFLOW package which compiles the Quality Model descriptions file (*.MOD) and generates a Quality Model output file (*.MOB) which can be read by the DUFLOW calculation process.

General Structure

Structures which can not be defined as other DMS-structures, for example weirs with forced underflow.

Initial Conditions

Initial values for Flow and Quality variables defined on nodes and schematization points required to start a DUFLOW computation.

MODUFLOW

Program with which one can simulate an integrated ground water and surface water problem by combining the ground water model MODFLOW and DUFLOW.

Network editor

Graphical editor that enables you to interactively draw the network schematization. Visually the Network Editor consists of the Network window and the Palette toolbar.

Node

Point from which one or more sections arise or end.

Object

Part of the network e.g. node, section or structure.

Output node

Points of the network where the results of the calculations are recorded.

Output window

Window containing messages about the progress of DMS-actions.

Pump

Pumping station in or near a waterway.

RAM

Precipitation runoff module (Dutch: Regen Afvoer Module)

With RAM one can calculate the supply of rainfall to the surface flow. RAM calculates the losses and delays that occur before the precipitation has reached the surface flow.

Scenario Manager

Part of DMS which makes it possible to work with several sets of input data within the same Project. The Scenario may contain the input data itself or it may refer to input data of another Scenario. Each Scenario registers several sets of data. Per set of data one may choose to save the data in the own Scenario directory or receive the data from another Scenario directory.

Schematization point

Extra points on a section used by the DMS calculation and on which output can be generated. On a schematization point one or more areas and discharge points may be defined

Section

Connection between two nodes.

Siphon

A circular pipe used to carry water over obstacles.

Trigger Condition

The variation of one parameter in one or more structures depending on actual hydraulic conditions.

Weir

A construction made to control the level on the upstream side with a free watersurface.

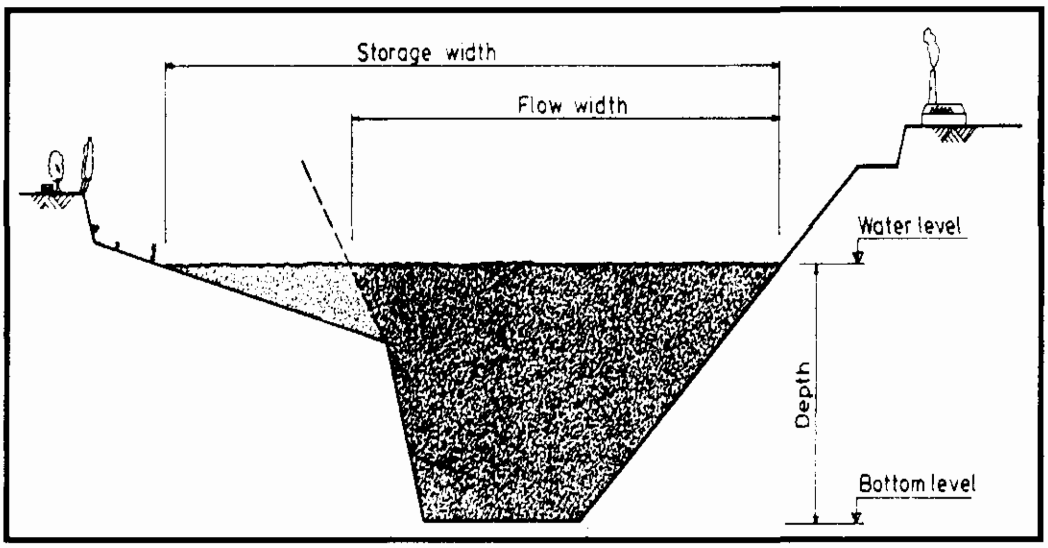
9. Index

Duflow

Reference Manual

VERSION 3.0 April 3rd 1998

Stowa / EDS



Contents

1. Introduction

1.1 History and purpose of the model

The introduction of personal or micro computers in organisations involved in water management and hydraulic engineering stimulated the demand for easy-to-use computer models.
Water authorities require a dynamic management of their extensive water systems and related infrastructure to provide water for industry, agriculture, domestic supply, fishery, energy and water quality control, taking into account reduction of damage due to excess of water, etc. In hydraulic engineering a proper design and operation of river based structures and improvement works also requires the consideration of larger parts of the overall water system.

In 1988 DUFLOW 1.0 was developed by a collaborate effort of the International Institute for Hydraulic and Environmental Engineering (IHE), the Faculty of Civil Engineering at Delft University of Technology and the Public Works Department (Rijkswaterstaat), Tidal Waters Division (now RIKZ).

Various educational institutes stressed on having free access to a hydrodynamic user-oriented computer code. The computational core of this model is based on the FORTRAN computer code IMPLIC which was originally developed by the Rijkswaterstaat. To improve its user orientation this IMPLIC code was fitted with a menu operated interface in 1989. Prior to this introduction, the use of computational models for unsteady flows in networks of open water courses was restricted to a small group of specialists.

In 1992 version 2.0 was completed. By order of the STOWA, the Agricultural University of Wageningen/ Department of Nature Conservation extended the program with water quality modelling, called DUPROL. Since the relationship between quality and flow receives special attention nowadays, a program suitable for modelling both aspects makes DUFLOW a useful tool in water quality management.

Because users also need to the ability to model the precipitation run-off process, the precipitation runoff module RAM was developed by Witteveen + Bos and EDS, by order of the STOWA.

With the introduction of DUFLOW 2.0, the maintenance of the package was supplied by EDS (then ICIM). The user may approach the helpdesk at EDS with questions and problems that arise when using DUFLOW, RAM and MODUFLOW.

DUFLOW is the joint ownership of Rijkswaterstaat, IHE, the Delft University of Technology, STOWA and the Agricultural University of Wageningen.

Furthermore, the KIWA and Dienst Weg- en Waterbouw (DWW) of Rijkswaterstaat have ordered the development of further extension of the DUFLOW product.

- KIWA: MODUFLOW, program which simulates an integrated ground-water and surface-water problem by combining the ground water model MODFLOW and DUFLOW.
- DWW : Gap Growth structure in DUFLOW

In the Water Quality part the process descriptions can be supplied by the user. This special concept enables the user to create different types of water quality models. Two predefined eutrophication models are included in the product.

In 1998 DUFLOW is migrated to Windows95/WindowsNT - DUFLOW 3.0 - and has become a component of theDUFLOW MODELLING STUDIO (DMS). In DMS the RAM component is integrated with the DUFLOW component. In the future also MODUFLOW will be available as a DMS-component.

A free student's version is available, which includes all options, but is restricted in the number of sections and external variables. Information on purchase and users rights will be supplied by EDS, Leidschendam, The Netherlands.

This chapter gives a general overview of the capabilities of the model and is intended for those who have to decide whether to use DUFLOW or not.

Chapter 2 gives an account of the physical and mathematical background; it provides advanced users with the necessary information on the assumptions and methodologies underlying the model.

Chapter 3 gives a language reference of the DUPROL program which is used to compile the process description file.

Chapter 4 gives a short description of some other applications.

1.2 Types of users

The DUFLOW product is designed for various categories of users. The model can be used by water authorities and designers and has proved to be a very useful tool in education. DUFLOW runs on a personal computer under Windows 95 or Windows NT and is supplied with a graphical user-interface. It can therefore be operated in almost every scientific or engineering environment.

The major advantage in engineering education is the short learning time which is due to its program structure and user-oriented input and output.

In water management the model can be used to simulate the behaviour of a system due to operational measure such as opening or closing of sluices, switching on pumping stations, reduction of pollutant loads etc. and thus to optimise the day-to-day management decisions and to evaluate management strategies.

In a consultancy environment the model can be used in the design of hydraulic structures, flood and salt prevention and river training measures.

1.3 Design considerations

DUFLOW is designed to cover a large range of applications, such as propagation of tidal waves in estuaries, flood waves in rivers, operation of irrigation and drainage systems, etc.

Basically, free flow in open channel systems is simulated, where control structures like weirs, pumps, culverts and siphons can be included.

As in many water management problems, the runoff from catchment areas is important, a simple precipitation-runoff relation is part of the model set-up in DUFLOW. With the DMS-component RAM the precipitation-runoff processes can be described in detail. The results of a RAM calculation can be used as input for a DUFLOW-calculation.

The selected numerical scheme allows for a rather large time step in the computation and for choosing different lengths of the elementary sections.

Water quality is an increasing concern in water management, e.g. problems of algal bloom, contaminated silt, salt intrusion etc. More often than not, water quality has to be described by a (sometimes large) number of parameters, therefore DUFLOW allows for a number of quality constituents, and it is able to model the interactions between these constituents. There is an abundance of formulations around, which gives a great freedom for the user in formulating the production or destruction of biological or chemical materials. To test such a formulation there is the possibility of a simple box model. For common users a number of pre-formulated interactions is available for which the coefficients can be influenced.

An important topic in water quality problems is also the interaction between the bottom layer and the water mass above; DUFLOW distinguishes transported materials that flow with the water and bottom materials that are not transported but that can be subject to similar interactions as described above.

The interaction between surface flow and ground water flow is also playing an important part in water management. When applying water management to the changes in physical planning, one must develop insight in the changes in the precipitation runoff.

DUFLOW can direct results to disk files which can be approached by other computer programs (e.g. economic analysis and structural design).

For immediate analysis, the results can be graphically displayed on the screen in time or space. Optionally output is given in the form of tables, while all output can be directed to a (graphical) printer.

DUFLOW is efficient both in terms of computation time and required memory, thus allowing the processing of large models. Computation time is usually in the range of minutes up to one hour.

1.4 Options and elements

In DUFLOW a model, representing a specific application, can be put together from a range of elements. Types of elements which are available are open channel sections (both river and canal sections), and control sections or structures such as weirs, culverts, siphons and pumps.

For instance an irrigation or drainage system consists of a network of (small) canals; water may be locally transported through pumps and siphons and in the network the discharges and levels may be controlled by means of weirs.

In case of a flood wave in a river the discharge imposed at the upstream boundary of a river stretch is transmitted through a sequence of river sections which may be separated by (movable) weirs.

Boundary conditions can be specified as:

- water levels and discharges, either constant or in the form of time series or Fourier series;
- additional or external flow into the network can be specified as a (time dependent) discharge or can be computed from a given rainfall, using the simple precipitation-runoff relation of DUFLOW or the extended precipitation-runoff module RAM;
- discharge-level relations (rating curves) in tabular form;

- concentrations and loads of all the transported materials in the quality model, either constant or in the form of time series or Fourier series.

Wind stress, which may be significant in extensive shallow networks, can also be included. All time series can directly be defined or can be read from an external ASCII file.

In the network window, the network schematization can be created and interactively adjusted. Simple shaped cross-sections can be specified with only a few data. Two types of resistance formulae can be used, viz. Manning and De Chézy.

For more complex cross-sections (natural rivers) the width (both width of flow and width of storage) and the friction factor and the hydraulic radius can be specified as a function of the water level.

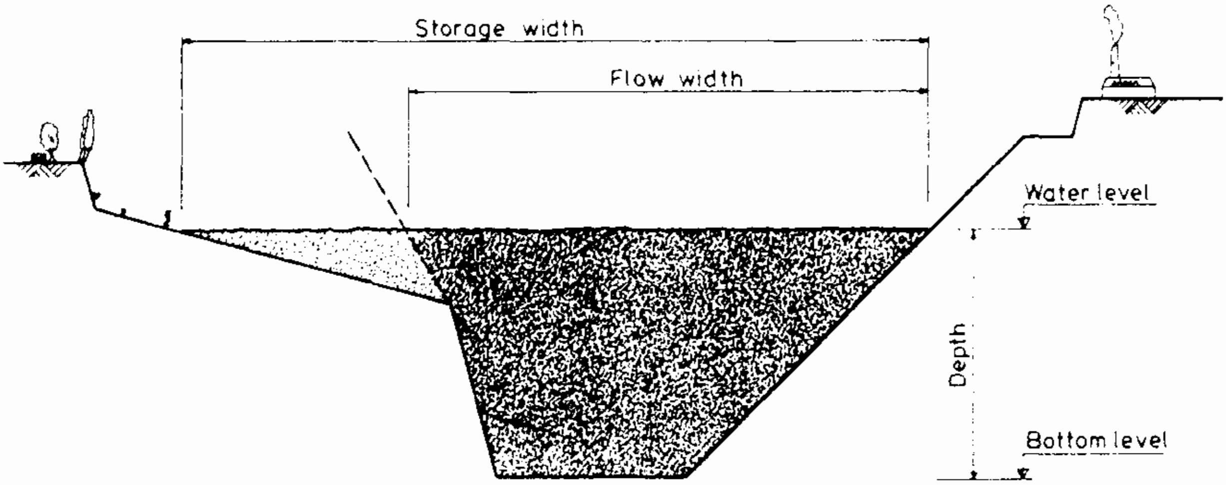


Figure 1.1 Cross sectional distribution

A range of control structures is available in DUFLOW:

Weirs with movable gates can be modelled for overflow and underflow (submerged) conditions. Transition between various flow situations such as overflow and underflow, sub- and supercritical flow in either direction takes place automatically.

During execution of the program the height and width of a gate can be modified depending on the actual computed water level(s) at a pre-defined location in the system and according to a pre-specified procedure (trigger conditions). Thus various strategies of 'automatic' gate manipulation can be specified.

A Culvert is represented as a weir by taking into account also the friction.

Pumps are automatically operated depending on the upstream level only.

Siphons are defined as circular pipes and the flow depends on the water levels at both sides. Friction losses are taken into account.

Elliptic culverts are represented by weirs with elliptic cross-sections.

A Gap growth structure, to simulate a dike burst, is represented by an overflow where the sill level decreases and the width of the overflow increases as time passes.

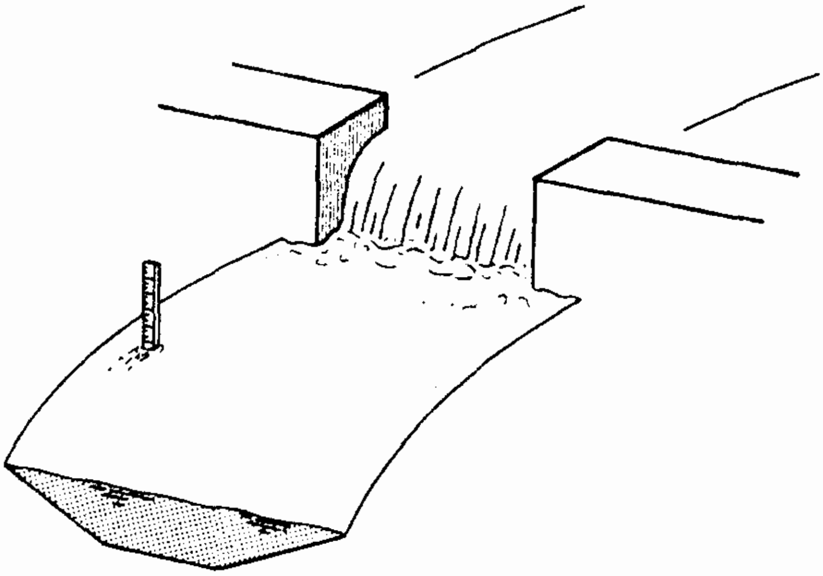


Figure 1.2 Sketch of a hydraulic structure.

1.5 Structure of the DUFLOW MODELLING STUDIO

The DUFLOW MODELLING STUDIO is developed under the Windows95/Windows NT operating system. The graphical user interface gives the user the possibility to manipulate and activate the objects of the model directly. Inexperienced users will have a short learning time due to the user friendly interface. The presence of context sensitive menu's and Shortcut Toolbars will contribute to quick operation of the system by experienced users.

The program consists of a Scenario Manager with which the user can define several different scenario's. The Network Editor enables the user to create a network of water courses by dragging and dropping the elements from the Network Palette. The network can be presented on a geographical background. The presentation module makes it possible to open several graphical windows, per Project several extra windows may be opened to give the user a complete overview of the results. The use of dockable windows has been applied, which places frequently used windows on the borders of the screen, avoiding overlap of other windows.

The DUFLOW MODELLING STUDIO consists of the following parts:

1. DUFLOW water quantity
   With this program one can perform unsteady flow computations in networks of open water courses.
2. DUFLOW water quality
   This program is useful in simulating the transportation of substances in free surface flow and can simulate more complex water quality processes.
3. RAM precipitation runoff module
   With RAM one can calculate the supply of rainfall to the surface flow. RAM calculates the losses and delays that occur before the precipitation has reached the surface flow.
4. MODUFLOW (not integrated in DMS 3.0)
   This program simulates an integrated ground-water and surface-water problem by combining the ground water model MODFLOW and DUFLOW.

2. Physical and mathematical background

2.1 Introduction

In this chapter an outline is given of the basic equations used in DUFLOW and the numerical procedures used to discretize and solve these equations.

Section 2.2 deals with the equations for unsteady flow in open channels. In special paragraphs the use of boundary-**Error! Bookmark not defined.**, initial conditions and structures is presented.

In section 2.3 the mass transport equation and numerical solution applied in the quality part are discussed. Special attention is paid to the use of boundary conditions and process descriptions.

Section 2.4 gives an outline of the numerical methods used. Finally in section 2.5 some practical considerations for the application of the model are given.

The equations presented in the sequel are often given in the form valid for a network. In a network any section connects two nodes, one of which is always denoted as 1 and the other as 2; it is determined by the user which node is taken as node 1 and which as node 2. Discharges and loads are taken to be positive if transferring mass from node 1 to node 2.

The numerical method is based on the use of both the mass conservation equation and the equation of motion in the section, and the use of the conservation equation (stating that the sum of the discharges is 0) in the nodes.

2.2 Flow

2.2.1 The unsteady flow equations

DUFLOW is based on the one-dimensional partial differential equation that describes non-stationary flow in open channels (Abbott, 1979; Dronkers, 1964).

These equations, which are the mathematical translation of the laws of conservation of mass and of momentum read:

$$\frac{\partial B}{\partial t} + \frac{\partial Q}{\partial x} = 0 \qquad (1)$$

and

$$\frac{\partial Q}{\partial t} + gA\frac{\partial H}{\partial x} + \frac{\partial(\alpha Q v)}{\partial x} + \frac{g|Q|Q}{C^2AR} = a\gamma w^2 \cos(\Phi - \phi) \qquad (2)$$

while the relation:

$$Q = v \cdot A \qquad (3)$$

holds and where:

t	time [s]
x	distance as measured along the channel axis [m]
$H(x,t)$	water level with respect to reference level [m]
$v(x,t)$	mean velocity (averaged over the cross-sectional area) [m/s]
$Q(x,t)$	discharge at location x and at time t [m^3/s]
$R(x,H)$	hydraulic radius of cross-section [m]
$a(x,H)$	cross-sectional flow width [m]
$A(x,H)$	cross-sectional flow area [m^2]
$b(x,H)$	cross-sectional storage width [m]
$B(x,H)$	cross-sectional storage area [m^2]
g	acceleration due to gravity [m/s^2]
$C(x,H)$	coefficient of De Chézy [m^2/s]
$w(t)$	wind velocity [m/s]
$\Phi(t)$	wind direction in degrees [degrees]
$\phi(x)$	direction of channel axis in degrees, measured clockwise from the north [degrees]
$\gamma(x)$	wind conversion coefficient [-]
α	correction factor for non-uniformity of the velocity distribution in the advection term, defined as: $\alpha = \frac{A}{Q^2}\int v(y,z)^2\,dydz$ where the integral is taken over the cross-section A. [m^2]

This mass equation (1) states that if the water level changes at some location this will be the net result of local inflow minus outflow. The momentum equation (2) expresses that the net change of momentum is the result of interior and exterior forces like friction, wind and gravity.

For the derivation of these equations it has been assumed that the fluid is well-mixed and hence the density may be considered to be constant.

The advection term in the momentum equation:

$$\frac{\partial(\alpha Q v)}{\partial x} \qquad (4a)$$

can be broken into

$$\alpha\left(2\frac{Q}{A}\frac{\partial Q}{\partial x} - \frac{Q^2}{A^2}\frac{\partial A}{\partial x}\right) \qquad (4b)$$

The first term represents the impact of the change in discharge. The second term which expresses the effect of change in cross-sectional flow area, is called the

Froude term. In case of abrupt changes in cross-section this Froude term may lead to computational instabilities.

The DUFLOW User's Guide describes how to manipulate this term.

2.2.2 Discretization of unsteady flow equations

Equations (1) and (2) are discretized in space and time using the four-point implicit Preissmann scheme.

Defining a section Δx_i from node x_i to node x_{i+1} and a time interval Δt from time $t = t^n$ to time $t = t^{n+1}$, the discretization of the water level H can be expressed as:

$$H_i^{n+\theta} = (1-\theta)H_i^n + \theta H_i^{n+1} \qquad (5)$$

at node x_i and time $t + \theta\Delta t$

and

$$H_{i+1/2}^n = \frac{H_{i+1}^n + H_i^n}{2} \qquad (6)$$

in between nodes x_i and x_{i+1} at time t.

In a similar way other dependent variables can be approached.

The transformed partial differential equations can be written as a system of algebraic equations by replacing the derivatives by finite difference expressions. These expressions approximate the derivatives at the point of references ($x_{i+1/2}$, $t^{n+\theta}$) as shown in Figure 2.1.

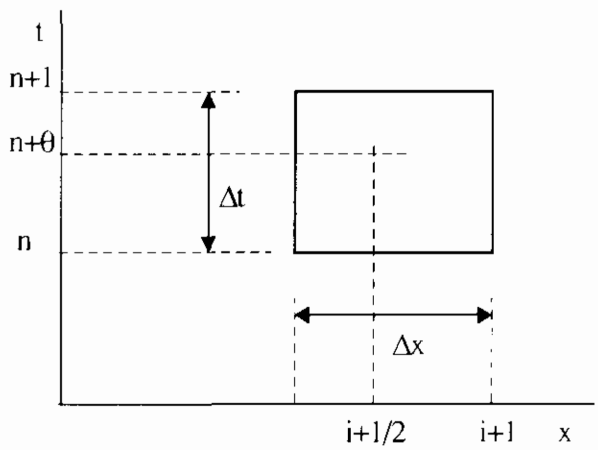


Figure 2.1 The Four Point Preismann scheme

With initially: $H_{i+1/2}^0 = H_{i+1/2}^n$

$$B_{i+1/2}^n = B_{i+1/2}\left(H_{i+1/2}^n\right)$$

$$b_{i+1/2}^n = b_{i+1/2}\left(H_{i+1/2}^n\right)$$

$$B_{i+1/2}^{n,*} = B_{i+1/2}^n - b_{i+1/2}^n H_{i+1/2}^n$$

equation (1) is transformed into:

$$\frac{B_{i+1/2}^{*,n+1} + b_{i+1/2}^{n+1} H_{i+1/2}^{n+1} - B_{i+1/2}^n}{\Delta t} + \frac{Q_{i+1}^{n+\theta} - Q_i^{n+\theta}}{\Delta x_i} = 0 \qquad (7)$$

and equation (2) into:

$$\frac{Q_{i+1/2}^{n+1}-Q_{i+1/2}^{n}}{\Delta t}+\frac{gA^{*}_{i+1/2}\left(H_{i+1}^{n+\theta}-H_{i}^{n+\theta}\right)}{\Delta x_i}+\frac{\alpha\left(\frac{Q^{*}_{i+1}}{A^{*}_{i+1}}Q^{n+1}_{i+1}-\frac{Q^{*}_{i}}{A^{*}_{i}}Q^{n+1}_{i}\right)}{\Delta x_i}+ \tag{8}$$

$$+\frac{g\left(Q^{n+1}_{i+1/2}\left|Q^{n}_{i+1/2}\right|\right)}{\left(C^2AR\right)^{*}_{i+1/2}}=a^{*}\gamma\ \left(w^{n+1}_{i+1/2}\right)\cos(\Phi^{n+1}-\phi)$$

A mass conservative scheme for water movement is essential for proper water quality simulation. If the continuity equation is not properly taken into account, the calculated concentration will not match the actual concentration. The mass conservative scheme is based on the fact that the error made in the continuity equation will be corrected in the next time step. Mass conservation is therefore guaranteed. The method used for this scheme is described in (Booij, 1978).

The * (like in $A^{*}_{i+1/2}$) expresses that these values are approximated at time $t^{n+\theta}$. This discretization is of second order in time and place if the value θ = 0.5 and it can be shown that in this case the discretized system is mass-conservative. In most applications, a somewhat larger θ-value, such as 0.55 is used in order to obtain a better stability (Roache, 1972).

The values indicated with (*) are computed using an iterative process. For example, a first approximation of A is

$$A^{*} = A^{n}$$

which is adjusted in subsequent iteration steps:

$$A^{*} = \frac{\left(A^{n} + A^{n+1,*}\right)}{2}$$

where $A^{n+1,*}$ is the new computed value of A^{n+1}.

So finally, for all channel sections in the network two equations are formed which have Q and H as unknowns on the new time level t^{n+1}:

$$Q_i^{n+1} = N_{11}H_i^{n+1} + N_{12}H_{i+1}^{n+1} + N_{13} \tag{9a}$$

$$Q_{i+1}^{n+1} = N_{21}H_i^{n+1} + N_{22}H_{i+1}^{n+1} + N_{23} \tag{9b}$$

2.2.3 Boundary and initial conditions

For a unique solution of the set of equations additional conditions have to be specified at the physical boundaries of the network and at the sections defined as hydraulic structures. Structures are discussed in section 2.2.4.

The user-defined conditions at the physical boundaries may be specified as levels, discharges or a relation between both. For instance a (tidal) elevation *H*, a discharge *Q*, or a so-called *QH* relation. The selection of boundary conditions is discussed in more detail in section 2.5.2.

At internal junctions the (implicit) condition states that the water level is continuous over such a junction node, and that the flows towards the junction are in balance since continuity requires:

$$\sum_{j=1}^{J} Q_{j,i} + q_i = 0 \tag{10}$$

where:

i indication for the junction node

$Q_{j,i}$ discharge from node j to node i

q_i additional or lateral flow to node i

The above equations are solved at each time step. They are transformed into a system of (linear) equations for the water levels by substitution of the equations (9a) and (9b). After the water levels are computed using a standard solution method for systems of linear equations, the discharges are found by substituting the computed water levels into equations (9a) and (9b).

Equation (10) is not used in nodes where a water level is prescribed as boundary condition. In such a node no equation is needed because the water level is already known. Discharge boundary conditions are taken into account as the additional flow q_i.

To start the computations, initial values for H and Q are required.

These initial values must be provided by the user; they may be historical measurements, obtained from former computations or just a first reasonable guess.

Additionally wind stress and rainfall conditions can be specified.

2.2.4 Structures

2.2.4.1 General about structures

Various types of control structures can be defined such as weirs, culverts, siphons and pumping stations, which cover most of the control structures existing in real-life systems.

At weirs and other structures discharges and levels can be controlled by manipulating the gates. DUFLOW allows for specification of such an operation using the so-called trigger conditions: depending on flow conditions at specified locations in the network, parameters such as the width of the weir, the level of the sill etc. can be adjusted during the computation. These conditions are treated in more detail in the DUFLOW User's Guide.

A common characteristic of structures is that the storage of water inside the structure is negligible compared with the storage in the open channels.
The definition of flow direction in a structure is the same as the definition in ordinary channel sections, flow from the begin node to the end node is assumed to be positive.

Any structureis defined between two nodes i and j and the discharge in the structure is denoted simply as Q.

2.2.4.2 Weirs

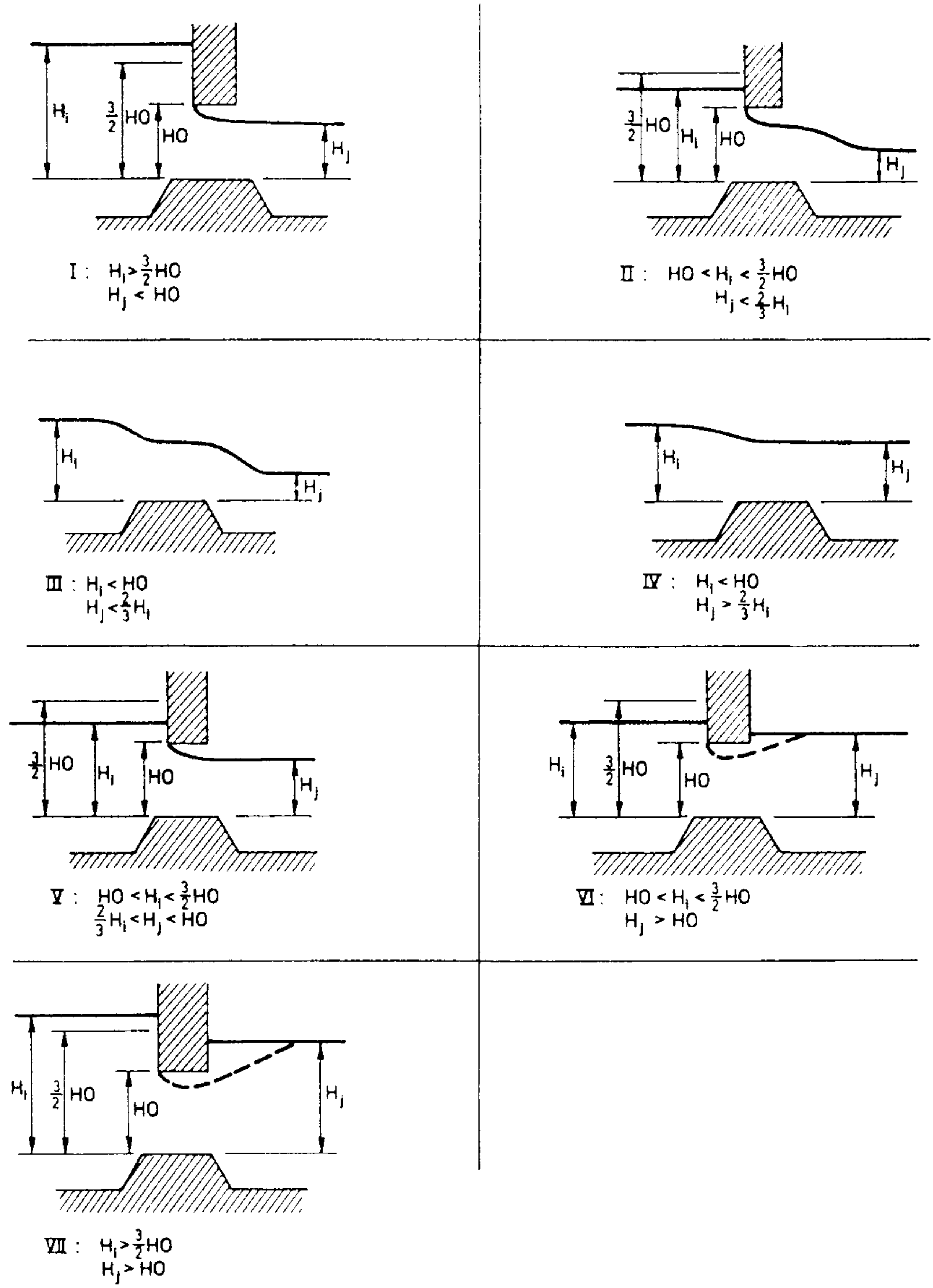


Figure 2.2 Weir Flow conditions, covered by DUFLOW

The discharge over a weir depends on the water level at both sides, the level of the sill, type of structures and the flow condition (free surface or submerged flow).

Figure 2.2 shows the seven hydraulic conditions of flow over a weir that can be distinguished, where it is assumed that $H_i > H_j$. If $H_i < H_j$, the picture is symmetrical with Figure 2.2 except for the loss coefficient, which need not be symmetrical.

The general equation for the discharge over the weir is

$$Q^{n+1} = \mu BH\sqrt{2g\Delta H} \tag{11}$$

where:

B	width of the weir,
μ	the discharge reduction or loss coefficient,
H	depth over the sill,
ΔH	difference in head.

These quantities, which may be different depending on the actual type and direction of flow, are given in Table 2.1

flow condition	DMS-object	μ	H	ΔH
I	General structure	μ_0	HO	$H_i^{n+1} - HO$
II	General structure	μ_t	$\frac{2}{3}H_i^{n+1}$	$\frac{1}{3}H_i^n$
III	Weir	μ_v	$\frac{2}{3}H_i^{n+1}$	$\frac{1}{3}H_i^n$
IV	Weir	μ_v	H_i^n	$H_i^{n+1} - H_j^{n+1}$
V	General structure	μ_t	H_i^n	$H_i^{n+1} - H_j^{n+1}$
VI	General structure	μ_t	HO	$H_i^{n+1} - H_j^{n+1}$
VII	General structure	μ_0	HO	$H_i^{n+1} - H_j^{n+1}$

Table 2.1 Coefficients in equation (11)

The parameters are defined as:

H_i, H_j	water depth over the sill, respectively at the beginning and at the end of the section
HO	height of gate opening
μ_0	loss coefficient, gate flow
μ_v	loss coefficient, free surface flow
μ_t	loss coefficient, transition between μ_0 and μ_v, i.e.

$$\mu_t = \mu_v + 2\left(\frac{H_i}{HO} - 1\right)(\mu_0 - \mu_v) \tag{12}$$

Note that these formulas are approximations of the real physical situation and can be calibrated using loss-coefficients μ_0 and μ_v.

Equation (11) is linearized and brought into the form generally used for structures:

$$Q^{n+1} = N_1 H_i^{n+1} + N_2 H_j^{n+1} + N_3 \tag{13}$$

2.2.4.3 Culverts

Culverts are governed by the same flow equations as weirs, only with a friction term added. This resistance is thought to be coupled serially with the weir, at the upstream side.

The equation for the resistance is based on the De Chézy formula:

$$Q = AC\sqrt{R\frac{\Delta H}{L}} \tag{14}$$

where ΔH is the head loss due to friction, and L is the length of the culvert as prescribed by the user. The quantities A, C, and R are defined in section 2.2.1.

The resistance formula is linearized as:

$$\left|Q^n\right| Q^{n+1} = \frac{A^2 C^2 R \Delta H}{L}$$

or

$$Q^{n+1} = \frac{A^2 C^2 R}{L\left|Q^n\right|}\Delta H = F \Delta H$$

Serial coupling means that a dummy node l is inserted between the nodes i and j. The formula for the discharge between the begin node i and the dummy node l is based on the resistance formula:

$$Q^{n+1} = F.\left(H_i^{n+1} - H_l^{n+1}\right).$$

and the formula for the discharge between node l and the end node j is equal to the weir formula:

$$Q^{n+1} = N_1 H_l^{n+1} + N_2 H_j^{n+1} + N_3$$

H_l is eliminated and the following result is obtained:

$$Q^{n+1} = \frac{FN_1}{F+N_1} H_i^{n+1} + \frac{FN_2}{F+N_1} H_j^{n+1} + \frac{FN_3}{F+N_1}$$

The general expression for the culvert is:

$$Q^{n+1} = N_1^* H_i^{n+1} + N_2^* H_j^{n+1} + N_3^* \tag{15}$$

where the coefficients for flow in both directions are:

$$N_1^* = \frac{F}{F + \max(N_1, -N_2)} N_1$$

$$N_2^* = \frac{F}{F + \max(N_1, -N_2)} N_2$$

$$N_3^* = \frac{F}{F + \max(N_1, -N_2)} N_3$$

2.2.4.4 Siphons

A siphon is a fully filled closed conduit to transport water over obstacles (hills, structures). In case of flow the equation for Q is the same as case VII in section 2.2.4.2, combined with resistance in the same way as in section 2.2.4.3.

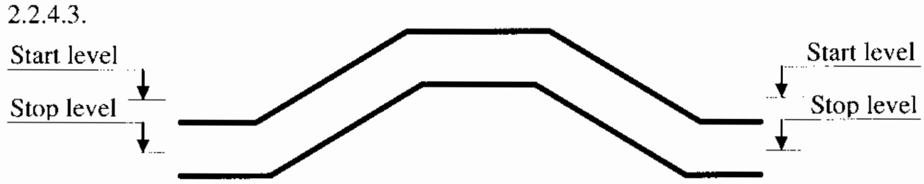


Figure 2.3 Operation levels of a siphon.

A siphon is in full operation when the upstream and downstream water levels are above the user defined start values. The siphon runs dry when at one of both sides the water level is below a user defined switch-off or stop level.

2.2.4.5 Pumps

A pump is assumed to be in full operation or not at all. Operation of the pump is controlled by the water level at upstream or begin node i.

There are two types of pumps that can be defined by the user. The first type is a drainage pump and the second is a so-called supply pump.

In the first type, the drainage pump water is carried from begin node to end node. For this type of pump the switch-on level (start level) must be higher than the switch-off (stop level). When the water level rises above the switch-on level, given by the user, the discharge is set to the pump capacity Q_p ,which is carried to the end node of the section. When the water level drops below the user defined switch-off level, the discharge is set to zero (see Figure 2.4).

For reasons of stability it may be necessary to define a reasonable additional storage capacity by introducing an extra section at node i.

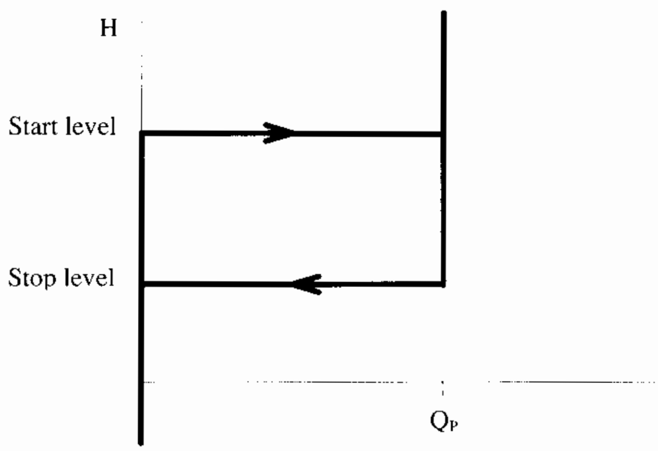


Figure 2.4 Dependence of drainage pump operation on upstream water level

The second type of pump is the supply pump Here water is carried from the end node to the begin node of the section. In other words, from a begin node viewpoint, a negative discharge is carried to the end node. In order for the user to define this supply pump the switch-on level (start level) must be below the switch-off level (stop level). When the water drops below the switch-on level, the supply of water by the pump is activated and the discharge is set to pump capacity $-Q_p$. When the water level rises above the switch-off level, the discharge is set to zero (see Figure 2.5).

Note that the function of the pump will determine itself if the discharge is positive or negative. The user must therefore give an absolute value of the pump capacity.

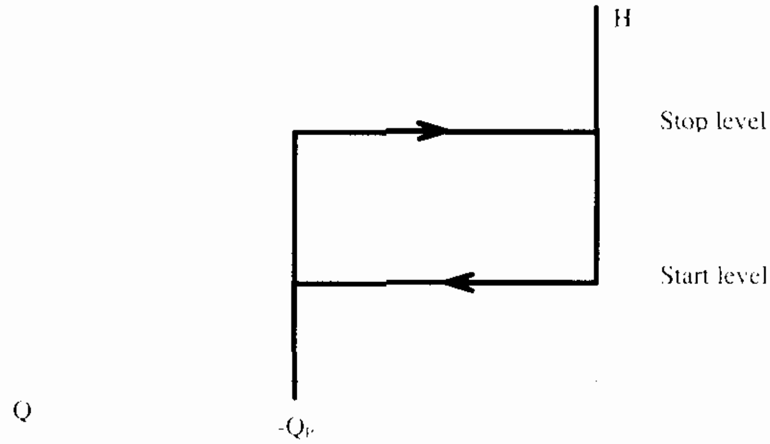


Figure 2.5 Dependence of supply pump operation on upstream water level

2.2.4.6 Gap growth structure (not available in DMS 3.0)

DUFLOW consists of the possibility to simulate the consequences of a dike burst. The development of a stream hole is modelled by a special type of structure, where the opening grows as time progresses. The calculation of the gap growth structure is based on the formulas of an overflow structure.

The gap growth structure uses the same variables as the overflow structure, such as the length of the gap, the initial sill level, the initial width, the gate level (default value) and the positive and negative free surface loss coefficients. Next to these variables, the structure is extended with six new variables. The six extra variables define the start trigger of the growth, the surplus height trigger, the maximal depth of the gap, the maximal width, the sill growth time and the width growth time.

The sill height with respect to a reference level decreases in the user defined gap growth time, starting from the initial sill height and ending at the maximum depth of the gap as defined by the user. Similarly, the width of the gap increases during the user defined width growth time, starting at the initial width of the gap and ending at the maximum width as defined by the user. The following options are possible to trigger the growth of the gap:

- the burst is activated by a starting time value, defined by the user
- the growth starts when the water level reaches the top of the dike (plus or minus a surplus height)

The equations used by the gap growth structure are the following:

$$H(t) = \begin{cases} H_{ini} - (H_{ini} - H_{max}) \cdot \sqrt{((t - T_{start})/Th_{max})} & \text{for } t < T_{start} + Th_{max} \\ H_{ini} & \text{for } t < T_{start} \\ H_{max} & \text{for } t > T_{start} + Th_{max} \end{cases}$$

$$B(t) = \begin{cases} B_{ini} + (B_{max} - B_{ini}) \cdot \sqrt{((t - T_{start})/Tb_{max})} & \text{for } t < T_{start} + Tb_{max} \\ B_{ini} & \text{for } t < T_{start} \\ B_{max} & \text{for } t > T_{start} + Tb_{max} \end{cases}$$

With

$B(t)$ gap width at time t [m]

B_{ini} initial width of the gap [m]

B_{max} maximal width of the gap [m]

H(t) gap height at time t [m]

H_{ini} initial sill level of the gap [m]

H_{max} maximal depth of the gap [m]

t current time step after start of computation [s]

T_{start} start time trigger of growth [s]

Tb_{max} width growth time[s]

Th_{max} sill growth time[s]

The maximal depth and maximum width must be given in meters, where the maximal depth is given with respect to the reference level. The sill growth time and width growth time are given in seconds.

A model that can be used to simulate the consequences of a dike burst may consist of the following schematization:

- a river consisting of several sections
- polder which consists of a matrix like network of several sections
- the structure type: gap growth.

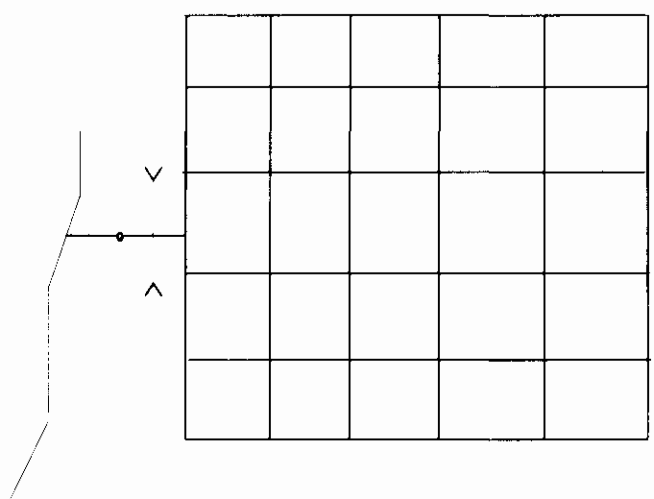


Figure 2.6 Schematization of model for simulation a dike burst

2.2.5 Dry flood procedure

A dry flood procedure is developed for the DUFLOW, which makes it possible to perform calculations with sections that become dry. At the same time, this method enlarges the stability of inclined systems with shallow brooks. A dry section is defined by a section where the calculated water has dropped beneath the defined bottom level of the section. Consequences of a dry section are that the flow area and the hydraulic radius of the section become equal to zero.

The dry flood procedure is as follows: the user defines a threshold value; when the calculated water level drops beneath this value, the width of the cross sectional profile decreases with an exponential function.

The advantage of this approach is that the transition to the dry flood procedure progresses smoothly, there is always water present in the system[1] and the user does not notice that the system has gone dry. In the model, all of the sections will remain containing water, which leads to the fact that dry sections never occur. In dry sections, therefore, the flow of water is always present. The measure to which this occurs depends on the value of the threshold defined by the user. A smaller threshold value will lead to a faster decrease, but in turn will increase the chance of instabilities.

The form of the exponential function is chosen in such a way that the water capacity of the original section beneath the threshold value is equal to the water capacity contained by the tube that arises with the new profile. This means that mass conservation is guaranteed. A mass conservative scheme is essential for a correct simulation of the water quality.

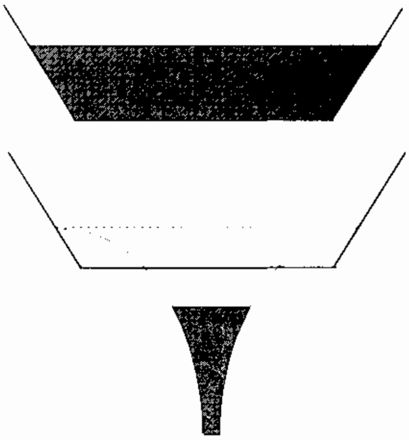


Figure 2.7 The Dry flood procedure

2.3 Quality

2.3.1 The mass transport equation

The quality part of the DUFLOW package is based upon the one dimensional transport equation. This partial differential equation describes the concentration of a constituent in a one dimensional system as function of time and place.

$$\frac{\partial (BC)}{\partial t} = -\frac{\partial (QC)}{\partial x} + \frac{\partial}{\partial x}\left(AD \frac{\partial C}{\partial x} \right) + P \qquad (16)$$

where:

C	constituent concentration [g/m³]
Q	flow [m³/s]
A	cross-sectional flow area [m²]
D	dispersion coefficient [m² /s]
B	cross-sectional storage area [m²]
x	x-co-ordinate [m]
t	time [s]

[1] In theory, the width of the profile never reaches zero. However, because of limited machine accuracy, the width will reach the value zero eventually. On the other hand, in practice this does not lead to problems.

P production of the constituent per unit length of the section [g/m.s]

The production term of the equation includes all physical, chemical and biological processes to which a specific constituent is subject to. In section 2.3.4 a detailed description of the way the processes are dealt with is presented. For the time being in this paragraph the overall production rate for constituent C is represented using the lumped variable P.

Equation (16) has to be solved numerically. The solution technique selected is the method used in model flows (Booij, 1978). In order to apply this method equation (16) is rewritten as:

$$\frac{\partial S}{\partial x} + \frac{\partial (BC)}{\partial t} - P = 0 \qquad (17)$$

in which S is the transport (quantity of the constituent passing a cross-section per unit of time):

$$S = QC - AD\frac{\partial C}{\partial x} \qquad (18)$$

Equation (18) describes the transport by advection and dispersion. Equation (17) is the mathematical formulation of the mass conservation law, which states that the accumulation at a certain location x is equal to the net production rate minus the transport gradient.

In this form the transport equation closely resembles the equations for the flow so that similar numerical approximations may be applied.

2.3.2 Discretization of the mass transport equation

The numerical method used to solve the transport equations (17) and (18) was adopted from the model flows (Booij, 1978). The method is unconditionally stable and shows little numerical dispersion. Furthermore, the method perfectly fits to the discretization of the flow equations. Similar to the flow computations, adjacent sections may be different in length.

In the flow computation the discharges at each end of a section are expressed as (linear) functions of the water levels at both ends. Here we express the transports at both ends (S_1 and S_2) into the concentrations at both ends (c_1 and c_2). To obtain such expressions we apply Galerkin's method.

The mass conservation equation (17) is integrated over the section, multiplied with a weighting function ψ_1 or ψ_2:

$$\int_0^{\Delta x} \psi_i \left[\frac{\partial S_i}{\partial x} + \frac{\partial (B_i C)}{\partial t} - P_i \right] dx = 0 \qquad (19)$$

results into:

$$\psi_i S_i \Big|_0^{\Delta x} + \int_0^{\Delta x} \left[\psi_i \frac{\partial (B_i C)}{\partial t} - \frac{\partial \psi_i}{\partial x}\left(QC - A_i D \frac{\partial C}{\partial x} \right) - \psi_i P_i \right] dx = 0 \qquad (20)$$

In each section we distinguish two weighting functions:

$$\psi_1 = 1 - \frac{x}{\Delta x} \qquad (21)$$

$$\psi_2 = \frac{x}{\Delta x} \qquad (22)$$

C is assumed to vary linearly within the section Δx, i.e.:

$$C = \psi_1 c_1 + \psi_2 c_2 \tag{23}$$

in which c_1 and c_2 are the concentrations at the beginning and the end of the section.

Solution of equation (20) for i = 1,2 results into:

$$\begin{aligned} -S_1 + \frac{\Delta x}{3}\frac{\partial B_1 c_1}{\partial t} + \frac{\Delta x}{6}\frac{\partial B_2 c_2}{\partial t} + \frac{Q_1 c_1 + Q_2 c_2}{2} - A_1 D \frac{c_2 - c_1}{\Delta x} + \\ -\frac{\Delta x}{3} P_1 - \frac{\Delta x}{6} P_2 = 0 \end{aligned} \tag{24}$$

$$\begin{aligned} +S_2 + \frac{\Delta x}{6}\frac{\partial B_1 c_1}{\partial t} + \frac{\Delta x}{3}\frac{\partial B_2 c_2}{\partial t} - \frac{Q_1 c_1 + Q_2 c_2}{2} + A_2 D \frac{c_2 - c_1}{\Delta x} + \\ -\frac{\Delta x}{6} P_1 - \frac{\Delta x}{3} P_2 = 0 \end{aligned} \tag{25}$$

In which indices 1 and 2 refer to the beginning and the end of the section. In equations (24) and (25) discretization with respect to x has taken place: the quantities S and C are still continuous functions of t.

Discretization of the equations (24) and (25) with respect to time using a time step Δt results into:

$$\begin{aligned} S_1^+ = -\frac{(1-\theta)}{\theta} S_1^- + \frac{\Delta x}{3\theta}\left(\frac{B_1^+ c_1^+ - B_1^- c_1^-}{\Delta t}\right) + \frac{\Delta x}{6\theta}\left(\frac{B_2^+ c_2^+ - B_2^- c_2^-}{\Delta t}\right) + \\ + \frac{\theta Q_1^+ c_1^+ + \theta Q_2^+ c_2^+ + (1-\theta) Q_1^- c_1^- + (1-\theta) Q_2^- c_2^-}{2\theta} + \\ - A_1 D \frac{\theta c_2^+ - \theta c_1^+ + (1-\theta) c_2^- - (1-\theta) c_1^-}{\Delta x \theta} - \frac{\Delta x}{3\theta} P_1 - \frac{\Delta x}{6\theta} P_2 \end{aligned} \tag{26}$$

$$\begin{aligned} S_2^+ = -\frac{(1-\theta)}{\theta} S_2^- - \frac{\Delta x}{6\theta}\left(\frac{B_1^+ c_1^+ - B_1^- c_1^-}{\Delta t}\right) - \frac{\Delta x}{3\theta}\left(\frac{B_2^+ c_2^+ - B_2^- c_2^-}{\Delta t}\right) + \\ + \frac{\theta Q_1^+ c_1^+ + \theta Q_2^+ c_2^+ + (1-\theta) Q_1^- c_1^- + (1-\theta) Q_2^- c_2^-}{2\theta} + \\ - A_2 D \frac{\theta c_2^+ - \theta c_1^+ + (1-\theta) c_2^- - (1-\theta) c_1^-}{\Delta x \theta} + \frac{\Delta x}{6\theta} P_1 + \frac{\Delta x}{3\theta} P_2 \end{aligned} \tag{27}$$

The indices + and - refer to the present and last time step respectively. The weighting factor with respect to time is θ. Using a value of θ = 1 results into a fully implicit method. In section 2.5 some practical considerations on the selection of θ are given.

Unknowns in the above equations are: c_1^+, c_2^+, S_1^+ and S_2^+. Normally but not always (see section 2.3.3.4 on "decoupling"), c_1^+ and c_2^+ are equal to the concentrations in the adjacent nodes so that S_1^+ and S_2^+ can be expressed into the concentrations at the nodes just like the discharges are expressed in the water levels at the nodes by (9a) and (9b):

$$S_i^{n+1} = N_{11} c_i^{n+1} + N_{12} c_{i+1}^{n+1} + N_{13}$$

$$S_{i+1}^{n+1} = N_{21}c_i^{n+1} + N_{22}c_{i+1}^{n+1} + N_{23}$$

Using these equations together with a mass balance over the nodes results into a set of linear equations which can be solved, see section 2.4. The figure below shows at which locations in the system matrix of the set of equations for C the submatrix N given above fits in. The coefficients N_{11}, N_{12}, N_{21} and N_{22} are found in the matrix E on the left hand side, the coefficients N_{13} and N_{23} appear in the right hand side (F):

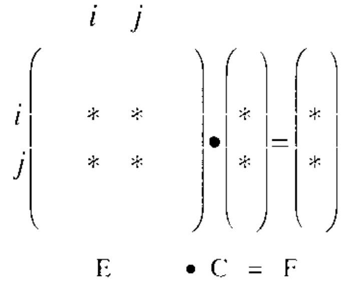


Figure 2.8 Structure of the set of equations

2.3.3 Boundary and initial conditions

2.3.3.1 Initial conditions

To start the computations, initial values for all state variables (concentrations) are required. These initial concentrations must be supplied for each node. They can be based on historical measurements, obtained from former computations or from a first reasonable guess.

In the last case the user should realise that the first part of the simulation period may result into non realistic results. The time during which the effect of the initial conditions is perceptible is controlled by the transport rates and the characteristic time constants for the reactions. As a rule of thumb for a single section, if only advection is taken into account, the impact of the initial conditions is completely gone after three times the residence time in this particular section.

As the exchange rates between the sediment layer and the overlying water are rather low especially for the concentrations in the sediment reasonable initial values have to be used. If no reasonable initial values are available it is recommended to perform some initial simulations from which the results, at the end of the simulation period can be used as initial values for a next run.

2.3.3.2 Boundary conditions

The way boundary conditions are treated in the quality part of DUFLOW is more complicated than for the flow part. Therefore this subject is discussed here with some more detail. In the first place we have to distinguish between two types:

- the physical boundaries of the system.
- the internal nodes in the system.

At the begin or end nodes in the network, in the flow part, a water level or discharge boundary can be applied. In the quality part at these locations a concentration boundary can be used. The different combinations of C and Q-H - boundaries are shown in the next paragraphs.

2.3.3.3 Physical boundaries of the network

H-boundary combined with C-boundary

- If the flow direction at node j is towards the environment:
  $S_2 = Q_2 c_2$
- If the flow direction at node j is into the network for S_2 equation (27) is used and in the mass balance equation for node j an additional load equal to $Q_2 c_b$ is added. Where c_b is the boundary concentration.

Q-boundary combined with C-boundary

- If the flow direction at node j is towards the environment:
  $S_2 = Q_2 c_2$
- If the flow direction at node j is into the network for S_2 equation (27) is used and in the mass balance equation for node j an additional load equal to Q_b c_b is added. Where Q_b and c_b are the flow and concentration at the boundary respectively.

Fixed concentration boundaries

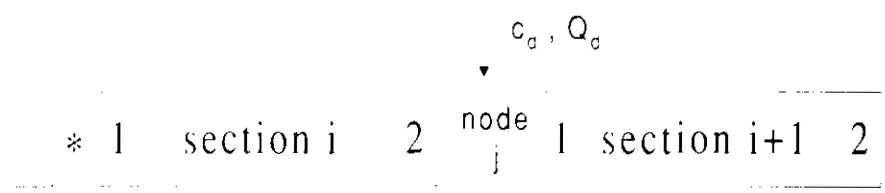
- If a C-boundary is defined at node j, without using an H or Q boundary. The specified concentration c_b is substituted in equation (27).

Dead end sections of the network

- If no H, Q or C boundary conditions are specified at node j: $S_2 = 0$. Physically this situation represents a dead end section of the network.

In case of physical H-boundaries, Q-boundaries and combined Q-H boundaries, a concentration boundary for every defined dissolved substance is compulsory.

2.3.3.4 Internal nodes



Q-boundary combined with C-boundary

This situation represents a discharge with a flow rate Q_d and a concentration c_d at node j in the network.

- If Q_d is positive (flow into the network): in the mass balance equation for node j an additional load Q_d c_d is added.
- If Q_d is negative an additional load equal - $Q_d c_{node}$ is added to the mass balance equation for node j. Where:
  $c_{node} = c_{1,i+1}$ if the flow in the network is positive (from i to i+1)

$c_{node} = c_{2,i}$ if the flow in the network is negative (from i+1 to i)

For the calculations of the mass transport in section i and i+1, two options are available in this case.

- If the calculation is performed using the option decouple (see calculation definition, paragraph 3.4.1.1, Decouple = Yes).
  $S_{2,i} = Q_{2,i} c_{2,i}$ if flow is from i to i+1
  $S_{1,i+1} = Q_{1,i+1} \cdot c_{1,i+1}$ if flow is from i+1 to i
  This means that the dispersion coefficient in the section downstream the discharge is set equal to zero (0).
- Default this decouple option is not used and the mass transport is calculated using equations (26) and (27).

This decouple option can be used to prevent flattening of steep concentration gradients at nodes where a discharge is located.

In case of a Q-boundary at an internal node, the user should either define a concentration boundary for <u>every</u> defined dissolved substance or define <u>no</u> concentration boundary at all for that internal node:

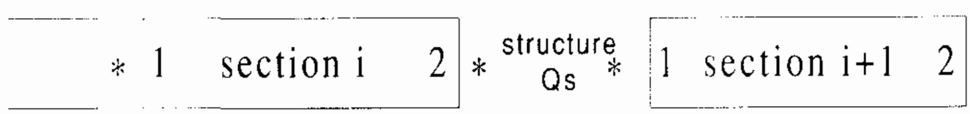
- Q-boundary combined with C-boundary for every dissolved substance.
  Water flowing in- and out of the model as defined above.
- Q-boundary, no C-boundary.
  Water flowing in- and out of the model contains no dissolved matter, C=0. This feature may cause confusion but is added to enable the user to model evaporation.

2.3.3.5 *Loads*

At all nodes in the network an additional load can be applied, which means that this load is added to the mass balance equation of the node. A load is expressed as a mass unit per second. The user should pay attention to the use of proper dimensions.

2.3.3.6 *Structures*

In structures no processes take place. Mass is only passed between the connected nodes.



If flow is from i to i+1: $S_1 = S_2 = Q_s\, c_{2,i}$

If flow is from i+1 to i: $S_1 = S_2 = Q_s\, c_{1,i+1}$.

2.3.4 Standard process descriptions

2.3.4.1 *General*

The DUFLOW water quality module has the property of having an open structure. The transport of substances through the water courses is described by the advection-diffusion equation. This equation in combination with DUFLOW water quantity is solved by DUFLOW for the given schematization. The description of the interaction between the different substances and organisms in the surface water is less trivial. The model description strongly depends on the problem.

Sometimes a simple process description is enough, however other times more complex process descriptions are necessary.

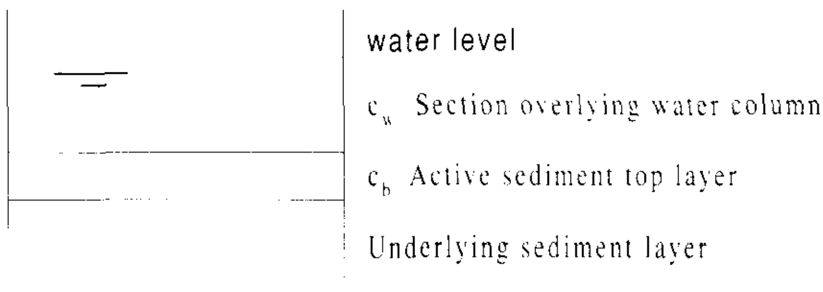
In DUFLOW the mathematical formulations describing the processes can be supplied by the user. They have to be supplied in the model file (*.mod), which can be created or edited using the user interface (see the DUFLOW User's Guide). For this purpose a special process description language has been developed. The set of process descriptions supplied by the user can be compiled using DUPROL. This compiler converts the descriptions into data, which are read by the calculation part of DUFLOW. In this way the user can change the process descriptions or define a new set of descriptions without changing and recompiling the source code of the calculation part of DUFLOW. A full explanation of the syntax of the language and the use of DUPROL is given in Chapter 3.

In the computational part the process descriptions are combined with the transport equations. Actually the lumped variable P introduced in equation (16) is filled in. In the preceding paragraph it was shown how the numerical solution of the mass transport equation resulted into a set of matrix equations. In this equation P is in the right hand side of the equation, which means that all process descriptions are evaluated using the values of the state variables at the previous time step. This explicit evaluation of the process description does have some consequences for the time step to be used. This subject is dealt with in section 2.6.

If more than one variable is defined in the process description file, the matrix equation is solved for each variable. This matrix equation is solved using LUD decomposition. Using this method the left hand side matrix has to be manipulated only once.

2.3.4.2 Bottom variables

DUFLOW water quality distinguishes between substances that are transported with the water phase, dissolved substances for instance and substances that are not transported with the water phase, but are connected to the bottom. This feature allows the user to include the bottom of the water course in the water quality model and to model the interaction of substances between water phase and bottom. Water type state variables have been dealt with in the previous part of this paragraph. For bottom state variables the transport part of equation (16) is not calculated. In this way for each section a bottom state variable can be defined to describe the interaction between the sediment and the overlying water column. The depth of the bottom layer and the transport across the water/sediment interface must be supplied by the user in the process description file.



In this example we consider an active sediment top layer. The thickness of this top layer is considered to be constant in time. If the porosity of the sediment is also assumed to be constant the exchange flux of a dissolved constituent between the sediment interstitial water and the water column can be expressed as:

$$F_{ex} = \frac{E_{ex}}{H_b}\left(c_w - \frac{c_b}{por}\right)$$

where:

F_{ex}	the exchange flux between water and sediment [g/ m^2. day]
E_{ex}	diffusive exchange rate [m^2 /day]
c_w	the constituent concentration in the overlying water column [g/ m^3]
c_b	the constituent concentration in the sediment [g/m^3]
H_b	thickness of the sediment top layer [m]
por	the porosity of the sediment top layer [-]

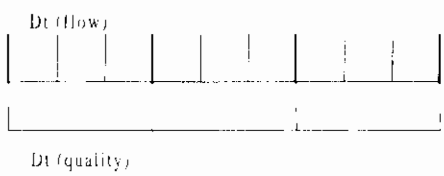
The description of the exchange flux has to be added to the differential equation describing the processes of the constituent. Both the depth of the sediment top layer and the exchange rate should be declared as a parameter.

In principle more complex descriptions can also be used to describe the sediment water interactions. Another example is given in EUTROF2 (see appendix B).

If necessary the sediment can be subdivided into more layers. The exchange between the distinguished layers can be expressed in the same way.

2.3.5 Options for computations

In DUFLOW four options for computation are available, see the DUFLOW User's Guide. Flow and quality can be calculated simultaneously or separately. In the last case the flow conditions (information like flow, flow width, etc.) are stored in the *.dmp file and read during simulation of quality. Different time steps can be used for calculation of flow and quality. The time step used for quality must be a multiple of the time step used for flow.



Using the option Box only the processes are simulated. Actually the transport related terms in equation (16) are eliminated. The processes are simulated in all sections of the network. Hence this option enables to evaluate the relative contribution of transport compared to the processes in the entire network. Furthermore, this option can be useful for testing during model development.

2.4 Solving the set of equations

The network as a whole is a system of sections and nodes, where each channel section and control structure is considered as a separate item. Each branch and node of the network has a unique identification number, assigned by the user. The structure of the system is implicitly defined by the user specification of node numbers at both ends of each section.

The number of unknowns is in principle equal to 2*J+I, where J is the number of sections and I is the number of nodes; in each branch the unknowns are the flows at both ends and at each node the water level. At structures the flow at begin and end node is the same.

The number of equations is also 2*J+I; for each channel section j two equations are derived, following from the mass and momentum equation (9). At structures only the momentum equation is applied (11, 14) as the mass equation can be neglected because of the no-storage condition. At each node there is a balance equation for the flows (10), since it is assumed in accordance with the four-point method that the storage of water takes place inside the branches, and not at the nodes. At boundary defined nodes an additional condition can be specified; thus there is one equation for each node.

Since the numerical scheme is implicit, a set of linear equations has to be solved for each time step.

Q_i and Q_{i+1} represent the discharge through cross-sections at the begin and end node of each section, and H and H_{i+1} represent the water level at these nodes.

After substitution of equation (9, 11, 14) into (10) a system of linear equations results in which the water levels are the unknown variables:

$$\sum_j M_{ij} H_j = R_i \qquad (30)$$

This system of equations is built up in the program section by section. For the channel section with nodes i and j, the coefficients N_{11}, N_{12}, N_{21} and N_{22} in equation (9) contribute to the matrix coefficients M_{ii}, M_{ij}, M_{ji} and M_{jj} respectively, and the coefficients N_{13} and N_{23} to R_i and R_j respectively. For control structures similar conditions hold.

In this way the structure of the network is recognisable in the structure of the system of equations, see Figure 2.9.

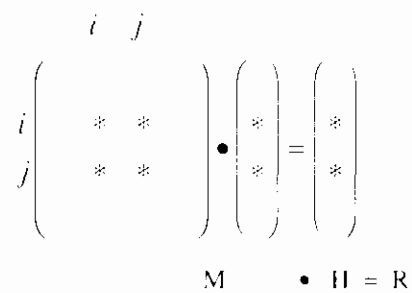


Figure 2.9 Structure of the set of equations

In most cases the matrix N is sparse, which means that most elements are zero with non-zero elements scattered over the entire matrix.

The solution method is based on LUD decomposition. For details of this method the user is referred to numerical handbooks. For instance (Numerical Recipes) a comprehensive description of LUD decomposition is given.

2.5 Practical considerations

In this paragraph a few suggestions are given concerning practical modelling aspects using the DUFLOW product. These suggestions are valid for any open channel network and are described in even more detail in the literature. Here only a brief outline is given.

Defining a model for a specific situation requires decisions like:

- extent of the computational region, in space and time;

- nature of boundary conditions;
- schematisation of channel sections, structures etc.;
- space and time discretization;
- type of quality model selected and level of detail used in process descriptions.

2.5.1 Extent of computational region, in space and time

DUFLOW is a predictive model, especially suited for the simulation of changes in existing systems. Simulation results of the actual situation can be verified, which is not the case for the simulation of the new situation.

Extrapolation of simulation results for quality to new situations also should be done carefully. A model might give an outstanding description of the present situation after calibration. But due to changing circumstances in the new situation the relative importance of certain processes may change. For example, after reduction of the external phosphorus load the release of phosphorus from the sediment may become important.

In particular, the boundaries must be chosen with great care in cases where a change in the system may effect a boundary condition which in turn may influence the hydraulic conditions and quality in the region of interest. Since the same boundary conditions are applied in the present and new situations, this may lead to erroneous results in the simulation of future changes. So one should take care that:

- either any change in the system does not affect a boundary condition;
- or the boundary condition does not influence the state in the region of interest.

For example, if a dam is planned in a river basin and one wants to predict the change in flood level at a location downstream of this dam, the upstream boundary should be chosen so far upstream that at that place no influence of the dam is expected.

The downstream boundary must be situated so far downstream that a wave reflected at this boundary is damped out at the location of interest. These choices can be verified by variations in the model: in case of the upstream boundary a computation with and without dam can be compared; in the case of the downstream boundary two computations with different locations of this boundary can be compared.

2.5.2 Nature of boundary conditions

When the location of a boundary is determined, the next choice is what type of boundary condition (water level, discharge of H-Q- relation) is to be used. The best choice is that quantity or relation that is least sensitive to the state in the model itself.

Thus the upstream boundary condition in a river is preferably a discharge whereas the downstream boundary condition should be a water level if the river flows into a lake or sea, or a H-Q relation based on uniform flow if the downstream boundary is somewhere along the river.

Note that a dead-end ($Q = 0$ permanently) is the default boundary condition in DUFLOW; such a boundary condition does not have to be mentioned explicitly in the program input.

When simulating quality a flow boundary in combination with a concentration boundary is used at the upstream boundaries of the network. At the downstream ends a concentration boundary condition is not necessary as long as the flow direction is directed towards the environment. In this case the upstream concentration is not influenced by the boundary condition. However if for some reason the direction of flow changes a concentration boundary should also be provided at these boundaries of the network.

Discharges at internal nodes in the network can be simulated using a Q and c boundary. However if the flow of the discharge is small compared to the flow in the receiving water also a load can be used.

2.5.3 Schematization of channel sections, structures, etc.

Very detailed schematisation of a network is seldom necessary due to the nature of the equations involved. Usually small changes in cross-sections have only little influence on the state in a region of interest.

It is useful to start with a rather crude model and to test the sensitivity of the model to small changes in cross-sections, before going to a detailed description. This is also true for structures.

For instance, it is not efficient to model every bridge or other obstacle as a separate structure. It is better to introduce an increased channel friction to compensate for this resistance. Only structures that considerably reduce the cross-section should be modelled explicitly.

In general, the level of detail used in quality simulation depends on both the nature of the system and the type of issues subject to modelling. The time and spatial scales of the variations in the concentrations are important in this respect. These scales are controlled by the rates of the underlying processes and the variability of the discharges and the environmental conditions.

Of course the desirable accuracy of the results also plays an important role.

Note: At both ends of a structure a normal section must be defined, in other words, a structure can not be located at the boundary of the model.

2.5.4 Space and time discretization

For space and time steps similar arguments apply. Very detailed description is often unnecessary. The space step must be such that changes in cross-section are reasonably well followed; furthermore the space step must be a small fraction (say 1/40th, or less) of the wavelength, if any. Also the time step must be a small fraction of the wave period. A sensitivity analysis giving the influence of the size of the time step is always recommended and easily carried out.

The selection of space and time steps also influences the numerical dispersion introduced by discretization of the mass transport equation. This numerical dispersion leads to an additional smoothing of concentration gradients. The numerical dispersion for the solution method used can be approximated by:

$$E_{num} = \frac{u}{2}(1-2\theta)u\Delta t \qquad (31)$$

For $\theta = 0.5$ this results into a numerical dispersion equal to 0. A value of $\theta < 0.5$ however may lead to a non positive solution, which may cause instabilities. A value of 0.55 is recommended.

As the production terms are calculated using the state at the preceding time step the selection of the time step used is also restricted by the process rates. As a rule of thumb, Δt should be less than half of the characteristic time constant of the fastest process.

In the spatial schematisation first nodes are selected at the boundaries of the network, at junctions, and at both sides of a structure (immediately adjacent to the structure). Subdivisions of the branches are applied whenever a branch is longer than the desired space step; denser subdivisions are applied in a region with rapid changes in cross-section. Neighbouring river sections with different length are not disadvantageous with regard to accuracy since the Preissmann scheme is used.

Finally, it must be stressed that applications by users without a proper understanding of phenomenon and/or without reliable verification increases the risk of erroneous results.

2.6 Limitations of the model

There are a number of inherent limitations in the equations and methods used in DUFLOW. The most important ones are summarised in this paragraph.

The equations are for one-dimensional flow. This means that the flow of the water in a section will be averaged over the width and depth of that section. DUFLOW is therefore not suitable for performing calculations of flows in which an extra spatial dimension is of interest. Water bodies with significantly different velocities in the vertical can therefor not be modelled. For instance the model is not suitable for stratified waters. Also the flow must be directed roughly parallel to the channel axis. Differences in flow velocity between the main channel and the flood plains can be taken into account by distinguishing the width of flow and the width of storage; however, if there are differences in water level between the main channel and the flood plains, it is better to model the two as separate (parallel) channels. A lake can be schematised by a network with several sections. The results, however, have limited validity.

As mentioned, vertical density differences are not taken into account; also horizontal density differences are not modelled because the density is assumed to be constant throughout. This is of interest in estuary, where a large concentration gradient has consequences for the water movement en where one may want to calculate the water movement to a high degree of accuracy.

Although the equations underlying the model are valid in case of supercritical flow, the numerical solution method does not support supercritical flow. In structures the calculation of super critical flow is not a problem. Because subcritical flow is assumed there must be one boundary condition at each of the boundaries of the network.

3. DUPROL

3.1 Language reference

The interactions involved without transport processes, advection and dispersion, need to be supplied by the quality model development part of the program. These are stored in the process description file *.mod. The resulting set of equations has to be compiled using DUPROL. After compilation a *.mob file is created which can be read by DUFLOW.

3.1.1 Syntax

DUPROL is not case sensitive.

Some rules of syntax:

- An *identifier* (name of a variable) starts with a character and consists of a maximum of six characters. Non alpha-numerical characters are not allowed. The name of variable *d* is reserved for the dispersion coefficient and should not be used, even not as a single character in the comments.
- *Comments* start with /* and end with */. Comments are only allowed at the beginning of the file.

A model file consists of two parts:

- Declaration section:
  In this part the different variables are defined.
- Compound statement:
  This part contains the equations describing the processes.

The *.mod file must be closed with an empty line at the bottom, otherwise DUPROL cannot compile the file correctly.

Choose to edit the model definition file if you want to develop the quality model. The program will ask which model definition file is to be edited. (*.mod). The editor will be activated so the desired process description file can be entered. A shortened example of a model definition file is shown below.

```
/*      Simple Eutrophication Model  EUTROF1.MOD   DUFLOW v2.xx                     */
/*                                                                                  */
/*      Hans Aalderink & Nico Klaver                                                */
/*                                                                                  */
/*                     Agricultural University of Wageningen                        */
/*                     Department of Nature Conservation                            */
/*                     Water Quality Management Section                             */
/*                     P.O. BOX 8080                                                */
```

```
/*                    6700 DL Wageningen                                  */
/*                    The Netherlands                                     */
/*                                                                        */
/*      September 1992                                                    */

water  A          [ 2.000]      mg-C/l          ;Algal biomass
water  PORG       [ 0.110]      mg P/l          ;Organic Phosphorus
water  PANORG     [ 0.040]      mg P/l          ;Inorganic Phosphorus
water  NH4        [ 0.300]      mg-N/l          ;Ammonia
water  NO3        [ 3.000]      mg N/l          ;Nitrate
water  NORG       [ 0.800]      mg N/l          ;Organic Nitrogen
water  O2         [10.000]      mg/l            ;Oxygen
water  BOD        [ 5.000]      mg-O2/l         ;BOD-5
water  SS         [ 5.000]      mg/l            ;Suspended Solids
parm   kp         [ 0.005]      mg-P/l          ;Monod constant Phosphorus
parm   kn         [ 0.010]      mg-N/l          ;Monod constant Nitrogen
parm   ealg       [ 0.016]      ug-Chl/l,m      ;Specific extinction chlorophyll
parm   e0         [ 1.000]      1/m             ;Background extinction
..
..
..
..
xt     sod        [ 1.000]      g O2/m2.day     ;Sediment Oxygen Demand
xt     i0         [10.00]       W/m2            ;Surface Light Intensity
xt     t          [20.00]       oC              ;Temperature
xt     resf       [  0.50]      g/m2.day        ;Resuspension flux Suspended Solids
xt     pflux      [  0.00]      g P/m2,day      ;Phosphorus release flux fromsediment
xt     nflux      [  0.00]      g N/m2,day      ;Ammonia release flux from sediment

flow   z          [  2.00]      m               ;Water depth
flow   Q          [  0.10]      m3/day          ;Flow
flow   As         [ 10.00]      m2              ;Cross sectional Area

{

fdpano=1/(1+kpip*SS);
PORTO=PANORG*fdpano;
Chla=achlc*A;

fn=MIN(PORTO/(PORTO+kp),(NH4+NO3)/(NH4+NO3+kn));
etot=e0+ealg*Chla;
ister=i0/is;
fl=2.71*(exp(-1*ister*exp(-1*etot*z))-exp(-ister))/(etot*z);
ft=tga^(t-20);
Groei=umax*fn*fl*ft;
Resp=kres*tra^(t-20)+kdie;
k1(A)=Groei-Resp;
..
..

Ptot=PORG+PANORG+A*apc;
Nkj=NORG+NH4+anc*A;
Ntot=Nkj+NO3;}
```

After editing the model file, leave the editor and choose to compile the model file. The program will translate the *.mod file into a *.mob file.

The *.mob file can be divided into a header, a section with declarations and the program section. The header contains the dimensions as defined by the water quality model. The section with declarations defines the substances that are used along with variables and parameters. The program part of the file contains the programming code of the quality model in reversed polish notation (RPN).

3.1.2 Declaration section

In the declaration section all different variables have to be defined. Five types of variables are distinguished.

water — Water column state variables. The flow has affect on this type of variable.

bottom — Sediment state variables. For these type of variables horizontal transport is omitted. Hence only the processes are calculated. Exchange between the sediment and the overlying water column should be described by the user. The flow has no effect on this type of variable.

xt	External variables, which are space and/or time dependent.
parm	Parameters, constants and coefficients used in the process equations.
flow	Flow variables, supplied by the hydraulic part of the model. These variables differ from the other variables by the fact that the identifiers of these variables are built-in. The following identifiers are available:

Z	Depth of water (m)
Q	Flow (m^3/s)
As	Flow area (m^2)
Ab	Storage area (m^2)
ds	Section direction(degrees - 360°, measured clockwise from the North)
dt	Quality time step (s)
dx	Half of the length of section (m)
V	Half of the volume of section (m^3)
Wf	Wind velocity (m/s)
Wd	Wind direction (degrees -360°, measured clockwise from the North)

water,
bottom,
xt,
parm,
flow

identifier

[default]

Dimension ;

Description <return>

Figure 3.1 Syntax of the declaration section

Default	Default values are used if the user does not supply values within the other menus. For the state variable the default values are used if the user does not enter initial conditions. The default value has to be given in between brackets `[' and `]'.
Dimension	The unit of the variable may consist of a maximum of 10 characters, followed by `;'. Longer names will be truncated. The unit of time in rate constants should always be defined in days.
Description	The description of the variable may not exceed a maximum of 40

characters. Longer lines will be truncated.

Below a part of the declaration section is given of the model description file.

```
/* Simple declaration section for explaining DUFLOW 2.00    */
/* remarks: No physical meaning               !!!           */
/* T.H.E. Editor, December 1995                             */

water   A       [ 2.000]  ug-C/l        ;Algal biomass
water   O2      [10.000]  mg/l          ;Oxygen
water   BOD     [ 5.000]  mg O2/l       ;BOD
water   SS      [10.000]  mg/l          ;Suspended solids

parm    kp      [ 0.005]  mg-P/l        ;Monod-constant P algal growth
parm    kn      [ 0.010]  mg-N/l        ;Monod-constant N algal growth
parm    ealg    [ 0.016]  ug Chl/l,m    ;Specific extinction algae
parm    e0      [ 1.000]  1/m           ;Background extinction of the water

xt      I0      [ 10.00]  W/m2          ;Irradiation
xt      T       [ 20.00]  oC            ;Temperature
xt      resf    [  0.50]  g-m2.dag      ;Resuspension  flux
```

3.1.3 Compound statement

3.1.3.1 Introduction

In this part the process descriptions have to be included. This section starts with '{' and should be closed '}'. All arithmetic expressions may be used (see next paragraph). The way the differential equations for the state variables should be entered needs some additional explanation.

For most state variables the kinetic derivative has the following form:

$$\frac{\partial C}{\partial t} = k_1 C + k_0$$

In this equation all first and zero order terms should be separated. For example the following equation:

$$\frac{\partial C}{\partial t} = k_a\left(C_s - C\right) - k_d L$$ should be rearranged like:

$$\frac{\partial C}{\partial t} = -k_a C + k_a C_s - k_d L$$

Internally lumped first and zero order coefficient are used, which should be defined by the user as:

$$k_1(C) = -k_a$$

$$k_0(C) = +k_a C_s - k_d L$$

If the k_1 and k_0 coefficient are not defined they will be set equal to zero.

For non state variables a function identifier is used. The declaration of these type of variables is implicit, which means that they may not be declared in the declaration section.

Three types of compound statements are available:

formula	See section 3.1.3.2
if-statement	See section 3.1.3.3
iteration-statement	See section 3.1.3.4

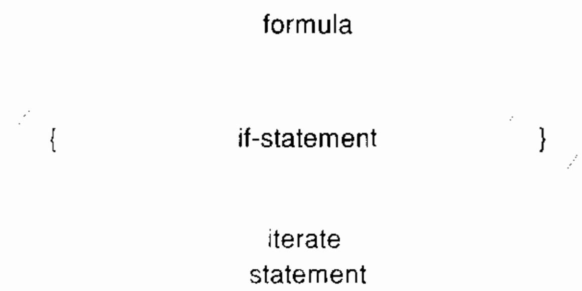


Figure 3.2 Syntax of the compound statement

3.1.3.2 Formula

The general syntax of a formula is shown in Figure 3.3

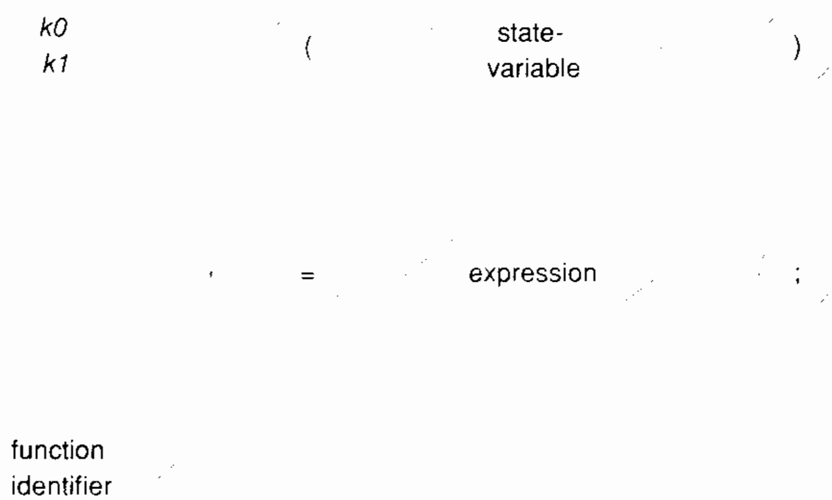


Figure 3.3 Syntax of Formula

k1	First order reaction coefficient.
k0	Zero order reaction coefficient.
state variable	Water or bottom state variable (maximal 6 characters).
function identifier	Identifier of a function (maximal 8 characters).
Expression	Definition of a function. A formula, defining the function identifier at right side of the equation. This formula consists off regular mathematic operators completed with several built-in functions . A function identifier is not allowed to appear in the right side of his own definition. A function identifier must already have been defined before it can be used in the right side of an equation. The following operators are available (in order of priority):

Arithmetic :	Built -in functions:
()	sin(x)
^ (to invoke)	cos(x)
*	tan(x)
/	exp(x) (ex)
+	ln(x)
-	log(x) (^{10}log(x))
	abs(x) (| x |)
	min(x1,x 2..... xn)
	max (x1. x2.... .xn)

3.1.3.3 If-statement

DUPROL contains a flow-control statement. The syntax of this statement is shown in Figure 3.4.

Figure 3.4 Syntax if statement

The *if statement* can be applied in several ways. The most common use of the statement will be shown in the following examples.

Example 1

Most basic formulation. If the condition in '(' and ')' is true the statement between the '{' and '}' will be executed.

```
if (NO3==0.0)
{
        pnh4=0.0;
}
```

Example 2

Example 1 can be extended with an alternative executable statement if the condition is false.

```
if (NO3==0.0)
{
        pnh4=0.0;
}
else
{
        pnh4= NO3/NH4*Kmn;
}
```

Example 3

If statements can be applied in several complicated situations, even nesting is allowed.

```
if (NO3==0.0)
{
```

```
        pnh4=0.0;
}
else if (NH4==0.0)
{
        pnh4= NH4/NO3*Kmn;
        if ((Kop>=1.0) && (Lap!=0.0))
        {
                Mip=pnh4*Kmn/2+0.001;

        }
}
else
{
        pnh4=NO3/NH4*Kmn;
}
```

General remarks concerning the use of if statements :

- Conditions can be defined using the following relational and logical (in order of priority):
  >
  >=
  <
  <=
  == (is equal to)
  != (unequal to)
  ! (not)
  && (and)
  || (or)
- Also in an if statement every executable statement must be closed with a ';'.
- Between the '{ }' the user can define a block of executable statements (= compound statement).

3.1.3.4 Iteration statement

In Figure 3.5 a syntax of an iteration statement is shown.

iterate (start value ,

tolerance identifier) compound statement

Figure 3.5 Syntax of iteration statement

The statement exists of:

start value	The start value of the variable of the iteration.
tolerance identifier	This variable (parameter) contains the maximum allowed difference between the two succeeding iteration results.
compound statement	The formula which has to be approximated by means of iteration.

An example is the iteration of the wavelength at depth D:

```
iterate      (LD=1.0, eps)
{
```

```
        LD= L * ((exp(+2*pie*D/LD))-(exp(-2*pie*D/LD) ))/
                ((exp(+2*pie*D/LD))+(exp(-2*pie*D/LD) ))
}
```

In which:

LD=1.0	, start value of the variable;
eps	, tolerance identifier;
LD= Function (L_D)	
	, function to be iterated;
pie	, $\pi = 3.1415927$;
L	, wavelength at the surface;
D	, depth.

4. Other applications

4.1 MODUFLOW

MODUFLOW is a module that performs an on-line link between MODFLOW and DUFLOW. MODUFLOW considers an existing MODFLOW schematization for the groundwater model and an existing DUFLOW schematization.

The dischargeto and from the groundwater to the water course has consequences for the water levelin this water course, on the other hand the water level influences the discharge to and from the groundwater. To investigate these interactions, the existing groundwater models and surface water models did not suffice. By performing the calculations of the two separate models successively one can not investigate the mutual influence they perform on each another. An on-line approximation is therefore necessary.

With MODUFLOWone can model the dynamic interaction between surface water and ground water. During the MODUFLOW schematization, the calculated MODFLOW discharges are sent to DUFLOW and the calculated water levels of DUFLOW are sent to MODFLOW.

MODUFLOWmaps both schematizations on top of each other. This results in determining the location per MODFLOW cell in each DUFLOW section. During calculation, MODUFLOW activates each model. The calculation switches between DUFLOW and MODFLOW for a certain time interval.

4.2 RAM

The Hydrologic Cycle is a continuous process in which water circulates from the oceans through the atmosphere and the rivers back to the ocean. Of the hydrologic cycle, the precipitation runoff model describes the process that occurs between the falling of the precipitation till the discharge developed by the run off to the ground water or surface water.

Precipitation runoff processes are generally described at a catchment area level. Within a catchment area, the relevant parameters may vary substantially, like the soil type, slope, land use, etc. A detailed physical description of the occurring processes is, therefore, difficult to give.

In RAM a division into types of surfaces is made:

Open water surface

Paved surface

Unpaved surface

A division into types of surface is made in view of the differences in precipitation runoff processes. For example, in case of an open water surface there will be no delay, in case of a paved surface a quick runoff process will occur, whereas an unpaved surface includes a slow component. Apart from this, the storage of moisture in the unsaturated zone of an unpaved surface is taken into account in a simple model.

Within the discharge process of unpaved surface, three processes are distinguished:

Infiltration into the soil moisture (unsaturated zone)

Percolation into the ground water (saturated zone)

Ground water discharge into the drainage system

By distinguishing between types of surface and between sub processes, the framework of the precipitation runoff module is defined.

In the next sections the three sub processes will be described.

4.2.1 Infiltration into the soil moisture (unsaturated zone)

The amount of precipitation that infiltrates is determined by the infiltration capacity of the soil, where the infiltration capacity is assumed constant in time. If the precipitation intensity surpasses the infiltration capacity, the remaining part of the precipitation will be stored on the surface level in the surface depressions. If the maximum storage in the surface depression is surpassed, the extra precipitation will runoff over the surface as surface runoff.

4.2.2 Percolation into the ground water (saturated zone)

A water balance of the amount of moisture in the unsaturated zone is maintained in the *soil moisture reservoir*. The replenishment of soil moisture in the soil moisture reservoir is the calculated infiltration, the outflow is calculated as the evaporation and the percolation to the ground water. Both the evaporation and the percolation depend on the actual soil moisture content.

4.2.3 Ground water discharge into the drainage system

The runoff of precipitation may consist of a slow and a quick component. The part of the precipitation that is drained quickly, is the quick component. It may consist of the runoff of precipitation into open water, surface runoff, interflow and runoff originating from drainpipes. The remaining effective precipitation is discharged quelled and slowed down to a relatively large extent, as a result of storage in the unsaturated and saturated zones (the slow component). This distinct was made because of the difference in characteristics of the processes and water qualityBoth the quick and slow component of the ground water discharge can be defined as a configuration of linear reservoirs. Two options are incorporated in the precipitation runoff module:

Two parallel Nash-cascades

Combination of Nash-cascade and Krayenhoff van de Leur

The distribution of the quick and slow component is performed by using a set percentage.

Using both options, it is possible to simulate all widely applied models from the literature.

4.2.4 Description of leaching and runoff

In the description of leaching and runoff we mainly consider supply, reaction processes in the bottom and discharge. Namely the reaction processes in the unsaturated zone are extremely complex. It is therefore decided not to model these reaction processes in RAM.

Point of departure for the description of water quality in RAM is a direct link with the discharge of the separate subflows and the water quality. Concentrations are attributed to the subflows, which are affected by the supply, the reaction processes and the discharge. These concentrations are worked out for nitrogen, phosphor and ammonium. The experience with this concept can be used to decide whether a more detailed concept is necessary or not.

5. File Formats

5.1 PRJ

The Project File is shown below, the case described in this appendix is EUTROF1 (see appendix A).

```
RIEUT1. CTR
RIVER.  NET
RIVER.  NOD
RIVER.  BEG
RIVER.  BND
RIVER.  RES
EUTROF1.MOB
RIEUT1. BEK
RIEUT1. BNK
RIEUT1. EXT
RIEUT1. PRM
RIEUT1. REK
```

The Project File contains a list of the files needed to run the complete model.

As an extra, an example of a measured data file (MEASUR.MSR) is added to this appendix. The name of this file is not stored in the PROJECT FILE.

In general the positions in the files are in use as following.

- For integers the program reserves 4 positions.
- For comments the program reserves 4 positions.
- For a real format the program reserves 6 positions, including the decimal. If the real format needs more then 6 positions, the format is written as a scientific format.

The values are separated by one space position or a '-'sign.

5.2 CTR

The Control File for the project (appendix A) is shown below.

```
+APPENDIX-A
* DUFLOW data file :C: DUFLOW\RIEUT1 RIEUT1.CTR
* Control data         program version: x.xx
*
TIME 910701a       0b910731c      0d910701e      0f
CONT 30.000g240.00h                              0i
           0.45j              0k       0l
     1.0000m     1n60.000o  0.55p      1q        1r
     PVAR
OUTS A    s
OUTV a    t
OUTV bod  u
OUTV nh4  v
OUTV no3  w
OUTV norg x
OUTV o2   y
OUTV panorg z
OUTV porg aa
OUTV chla ab
```

The following list gives an explanation about the items in the file.

If the first line starts with: +, it gives an identification of the run. This identification can only be specified in the DOS-version of DUFLOW. The lines 2 till 4 gives information about the related project as comment.

a	"Start of computation" (date) in yymmdd			
b	"Start of computation" (time) in hhmm			
c	"End of computation" (date) in yymmdd			
d	"End of computation" (time) in hhmm			
e	"Start of output" (date) in yymmdd			
f	"Start of output" (time) in hhmm			
g	"Time step flow" in minutes			
h	"Time step output" in minutes			
i	"Resistance formula"		0=Manning	1=De Chezy.
j	1 - "theta", hydraulic part of the model.			
k	"Calc. of advection term"	0=Total	1=Neglected	2=Damped.
l	"Extra iteration"	0=No	1=Yes	
m	"Alpha (corr. for velocity distribution)"			
n	"Minimum # timesteps between triggers"			
o	"Timestep quality" in minutes			
p	"Theta", quality part of the model.			
q	"Decouple"		0=No	1=Yes
r	"Create intermediate flow file"		0=No	1=Yes
*	Dependent on the specification in "Locations for output", several lines will be inserted representing that particular specification. For instance: "Extended"=All:			

```
PVAR  1    2    3    4    5    6
PVAR  7    8
```

s	"Locations for output", sectionnumber(s) or structure number(s)(+300) separated by a comma or a dash, or All.
t	"Quality variables for output", selected variable 1=a.
u	"Quality variables for output", selected variabel.2=bod
v	"Quality variables for output", selected variabel.3=nh4
w	"Quality variables for output", selected variabel.4=no3
x	"Quality variables for output", selected variabel.5=norg
y	"Quality variables for output", selected variabel.6=o2
z	"Quality variables for output", selected variabel.7=panorg

aa "Quality variables for output", selected variabel.8=porg
ab "Quality variables for output", selected variabel.9=chla

5.3 NET

The Network File contains data from the Network Window including the nodes, sections, crossections and all available structures.

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\RIVER.NET
*   Network data        program version: x.xx
*
SECT  1a          1b      1c        2d   5000e  -2.00f  -2.00g  30.00h  30.00i
W             270.0j     3.0k
H     0.0000l 2.0000m
BS    10.000n 10.000o

SECT  2           2       2         3    5000   -2.00   -2.00   30.00   30.00
W             270.0      3.0
H     0.0000  2.0000  2.5000  3.0000
BS1   10.000p 10.000  11.000  14.000
BS2   10.000q 10.000  13.000  15.000
BB1   10.000r 10.000  13.000  20.000
BB2   10.000s 10.000  13.000  22.000

SECT  3           3       3         4    5000   -2.00   -2.00   30.00   30.00
W             270.0      3.0
H     0.0000  2.0000
BS    10.000  10.000
A1            18.000t
A2            18.010u
R             1.3000v
C+            29.000w
C-            31.000x

SECT  4           4       4         5    5000   -2.00   -2.00   30.00   30.00
W             270.0      3.0
H     0.0000  2.0000
BS    10.000  10.000
```

The following list gives explanation about the items in the file.

a "section/structure" name by the user.
b section number (+300).
c "Begin Node" of the section.
d "End Node" of the section.
e "Length" of the section.
f "Bottom level", begin.
g "Bottom level", end.
h "Resistance", positive direction.
i "Resistance", negative direction.
j "Direction"
k "Windconv"
l 1st "Depth to bottom"
m 2nd "Depth to bottom", etc.
n 1st "Flow width".
o 2nd "Flow width", etc.
p 1st "Flow width" at the begin of the section.
q 1st "Flow width", at the end of the section.
r 1st "Storage width" at the begin of the section.
s 1st "Storage width", at the end of the section.
t Adjusted "Flow area" at the begin of the section.
u Adjusted "Flow area" at the end of the section.
v Adjusted "Hydraulic radius"
w Adjusted "Resistance" in the positive direction.
x Adjusted "Resistance" in the negative direction.

This is an example where no structures are defined. The next part will deal with the available structures in the DMS. The following structures are involved:

- Weir;
- General structure;
- Siphon;
- Culvert;
- Pump;
- Gap growth.

5.3.1 Weir

Below a weir example is shown.

```
STRU    1[a]     301[b]     2[c]       3[d]       0[e]  -1.30[f]  -5.00[g]   999.0[h]
MU    0.990[i]  0.980[j]
```

The following list gives explanation about the items *in an overflow*.

a	"section/structure" name by the user (no meaning).
b	structure number (+300).
c	"Begin Node" of the weir.
d	"End Node" of the weir.
e	"Length" of the weir.
f	"Sill level", weir.
g	"Width", weir.
h	"Gate level", in case off a weir is set to 999.0.
i	"Mu", positive direction weir.
j	"Mu", negative direction weir.

5.3.2 Underflow

The next example deals with a general structure.

```
STRU    2[a]       302[b]       4[c]        5[d]       0[e]  -1.75[f]   9.99[g]   -0.25[h]
MU   1.0E-8[i]  0.970[j]  0.960[k]  0.800[l]
```

The following list gives explanation about the items in a general structure.

a	"section/structure" name by the user.
b	structure number (+300).
c	"Begin Node" of the general structure.
d	"End Node" of the general structure.
e	"Length" of the general structure.
f	"Sill level", general structure.
g	"Width", general structure.
h	"Gate level", general structure.
i	"Mu free surface", in positive direction.
j	"Mu free surface", in negative direction.
k	"Mu submerged flow", in positive direction.
l	"Mu submerged flow", in negative direction.

5.3.3 Culvert

The next example deals with a culvert.

```
STRU   3[a]    303[b]    6[c]    7[d]   100[e]   3.80[f]   2.50[g]   1.40[h]
MU     1.60[i]  0.99[j]  0.99[k]  0.83[l]  50.0[m]
```

The following list gives explanation about the items in an culvert.

*	Tube form of the culvert;
	MU = Rectangular
	ELLI = Elliptic, Egg or Round
a	"section/structure" name by the user.
b	structure number (+300).
c	"Begin Node" of the culvert.
d	"End Node" of the culvert.
e	"Length" of the culvert.
f	"Horizontal radius", culvert.
g	"Vertical radius", culvert.
h	"Inside level", culvert.
i	"Sill level", culvert.
j	"Mu free surface", in positive direction.
k	"Mu free surface", in negative direction.
l	"Mu submerged flow".
m	"Chezy coefficient", culvert.

5.3.4 Siphon

The next example deals with a siphon.

```
STRU   4[a]    304[b]    8[c]    9[d]   1000[e]   1.10[f]  10.00[g]   0.68[h]  0.78[i]
SIPH   0.00[j]  -0.50[k]  -1.50[l]  -1.25[m]
```

The following list gives explanation about the items in a siphon.

a	"section/structure" name by the user.
b	structure number (+300).
c	"Begin Node" of the siphon.
d	"End Node" of the siphon.
e	"Length" of the siphon.
f	"Diameter", of the siphon.
g	"Chezy coefficient", culvert.
h	"Mu", in positive direction.
i	"Mu", in negative direction.
j	"Start level", at the begin of the siphon.
k	"Stop level", at the begin of the siphon.
l	"Start level", at the end of the siphon.
m	"Stop level", at the end of the siphon.

5.3.5 Pump

The next example deals with a pump.

```
STRU   5[a]      305[b]    15[c]    16[d]
PUMP 0.6000[e]   0.93[f]   0.10[g]
```

The following list gives explanation about the items in a pump.

a	"section/structure" number by the user.
b	structure number by duflow.
c	"Begin Node" of the pump.
d	"End Node" of the pump.

e	"Capacity", of the pump.
f	"Start level beg.".
g	"Stop level beg.".

5.3.6 Gap growth

The next example deals with a gap growth.

```
STRU     6a       306b      17c        18d        0e  -1.00f  -5.00g   999.0h
BRES  1.000i   1.000j  349200k          0l      0.5m    10.0n    5400o    5400p
```

The following list gives explanation about the items in a gap growth.

a	section/structure name by user (no meaning)	
b	structure number (+300)	
c	begin node of gap growth structure	
d	end node of gap growth structure	
e	length of gap growth structure	
f	initial sill level of gap growth structure	
g	initial width of gap growth structure	
h	gate level (set to 999.0)	
i	mu free surface positive direction	default = 1
j	mu free surface negative direction	default = 1
k	gap growth start time trigger in seconds	default = 0 s
l	gap growth start height trigger (surplus height)	default = 0.
m	maximal depth of gap	default = f. (initial sill level)
n	maximal with of gap	default = g. (initial width)
o	sill growth time in seconds	default = 0 s
p	width growth time in seconds	default = 0 s

5.4 NOD

In the Nodes File all data related to the nodes are stored.

```
* DUFLOW data file :C:\DUFLOW RIEUT1 RIVER.NOD
*   Network data       program version: x.xx
*
* file :C:\DUFLOW RIEUT1 RIVER.NOD
*  x.xx
*
+EI    a    0.0b
      1c      5000d            0e       0E+00f    0.00g
      2      10000             0        0E+00     0.00
      3      15000             0        0E+00     0.00
      4      20000             0        0E+00     0.00
      5      25000             0        0E+00     0.00
```

The following list gives explanation about the items in the file.

a	Code.
b	Orientation of network.
c	"Node" number.
d	"X-Coordinate" of the 1st node.
e	"Y-Coordinate" of the 1nd node.
f	"Catchment area" of the 1st node.
g	"Runoff factor" of the 1st node.

5.5 BEG

In the Initial Conditions - Flow File all initial conditions related to the flow are stored.

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\RIVER.BEG
* Flow  Initial conditions      program version: x.xx
*
   1a0.0000b0.0000c1.0000d1.0000e
   2 0.0000 0.0000 1.0000 1.0000
   3 0.0000 0.0000 1.0000 1.0000
   4 0.0000 0.0000 1.0000 1.0000
```

The following list gives explanation about the items in the file.

a number of the section or structure (+300).
b "Initial levels", at the begin of the section/structure.
c "Initial levels", at the end of the section/structure.
d "Initial discharges", at the begin of the section/structure.
e *"Initial discharges", at the end of the section/structure.*

5.6 BND

In the Boundary Conditions - Flow File all the boundary conditions related to the flow are stored.

5.6.1 Constant

Below is shown the boundary condition flow file (river.Bnd), in the appendix A (EUTROF1).The given example deals with a constant "Level"and "Q-add" boundary type.

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\RIVER.BND
* Flow  Bound. cond./struct ctrl.     program version: x.xx
*
H   a                                          2e          5b
P   c0.0000d
Q   a                                                      1b
P   c1.0000d
```

The following list gives explanation about the items in the file.

a "Type" of boundary:
H = "Level";
Q = "Q add.";
R = "Rain"(Precipitation);
W = "Wind velocity";
T = "Wind direction".
b "Node(s)" number.
c "Type of function" = "Constant".
d Entered value for "Constant".
e Condition number.

5.6.2 Equidistant time series

Below an example is given, dealing with a "Level" boundary type with "Equidistant time series" specification.

```
H a        240 b  1231 c      1 d      2 e                1 f
   1.0010 g 1.0020 h 1.0030 i 1.0040 j 1.0050 k 1.0060 l
   1.0070 m
```

The following list gives explanation about the items in the file.

a	"Type" of boundary:		
	H	=	"Level";
	Q	=	"Q add.";
	R	=	"Rain"(Precipitation);
	W	=	"Wind velocity";
	T	=	"Wind direction".
b	"Time step" in minutes.		
c	"Start data", in yymmdd.		
d	"Start time", in hhmm		
e	condition number		
f	"Node(s)" number.		
g	1st value of "Time series"		
h	2nd value of "Time series"		
:	:	:	:
l	6th value of "Time series"		
m	7th value of "Time series"		

5.6.3 Non-equidistant time series

Below an example is given, dealing with a "Level" boundary type with "Non-equidistant time series" specification.

```
Q a            0 b                      1 c               1 d
   960201 e  1200 f  2298 g
   960203    1100    2194
   960210    2100    2114
   960211    0900    2061
   960212    0900    2130
   960223    1200    2441
   960224    1200    3125
```

The following list gives explanation about the items in the file.

a	"Type" of boundary:		
	H	=	"Level";
	Q	=	"Q add.";
	R	=	"Rain"(Precipitation);
	W	=	"Wind velocity";
	T	=	"Wind direction".
b	"Time step" in minutes, always '0' in case of a non-equid. time series		
c	condition number.		
d	"Node(s)" number.		
e	"Date", in yymmdd.		
f	"Time", in hhmm		
g	value of "Time series"		

5.6.4 Fourier series

Below an example is given, dealing with a "Level" boundary type with "Fourier series" specification.

```
H   ^a       720^b 960101^c  0000^d       1^e                      1^f
P   ^g    3.5^h
       0.5^i   180^j
```

a — "Type" of boundary:

H	=	"Level";
Q	=	"Q add.";
R	=	"Rain" (Precipitation);
W	=	"Wind velocity";
T	=	"Wind direction".

b — Period in minutes.
c — "Start date", in yymmdd.
d — "Start time", in hhmm
e — Condition number.
f — "Node(s)" number.
g — "Type of function" = "Constant"
h — "Mean value"(y_0 in Fourier series).
i — Entered value for "Amplitude" of k^{th} component
j — Entered value for "Phase" of k^{th} component

5.6.5 QH relation

Below an example is given, dealing with a "QH-relation" boundary type.

```
QH  ^a                                                          2^b
HI  ^c    0.99^d    0.98^e    0. 97^f    0.96^g    0.95^h
QI  ^i  1.0100^j  1.0200^k  1.0300^l  1.0400^m  1.0500^n
```

The following list gives explanation about the items in the file.

a — Indication "QH-relation" boundary type.
b — "Node(s)" number.
c — Indication "Levels"
d — 1st value for levels.
e — 2nd value for levels.
: — : : : :
g — 4th value for levels.
h — 5th value for levels.
i — Indication "Discharges"
j — 1st value for discharges.
k — 2nd value for discharges.
: — : : : :
m — 4th value for discharges.
n — 5th value for discharges.

5.6.6 Structure control - continuous

The following example deals with a "continuous" structure control.

```
WIDT[a]                                                302[b]
P   [c]4.9900[d]
SILL                                                   302
P      1.9900
GATE                                                   302
P      1.5000
MU                                                     302
P      0.9700
```

The following list gives explanation about the items in the file.

a	Indication "Operational parameter" in "Continuous":		
	WIDT	=	"Width";
	SILL	=	"Sill level";
	GATE	=	"Gate level";
	MU	=	"Mu (all)".
b	"Structure" number (+300).		
c	Indication "Constant" timeseries.		
d	Value "Operational parameter".		

5.6.7 Structure control - trigger series

The following example deals with "Trigger series" in the structure control.

```
TMV1[a]                                                303[b]
TIME[c]101010[d]      10[e]
H2H1[c]    32[f]       0[g]
H1H2[c]  2400[h]       0[g]
       34.000[i]
HPP [c]     5[j]       0[k]     33[f]
HPM         6          0        34
```

The following list gives explanation about the items in the file.

a	Indication "Operational parameter" in "Trigger series":		
	TSIL	=	"Width";
	TWID	=	"Sill level";
	TGAT	=	"Gate level";
	TMU	=	"Mu (all)";
	TMV1	=	"Mu surf.pos.";
	TMV2	=	"MU surf. neg.";
	TMO1	=	"MU subm. pos.";
	TMO2	=	"MU subm. neg.".
b	"Structure" number (+300).		
c	"Type of trigger condition":		
	TIME	=	"Time";
	H2H1	=	"H2 < H1+δH";
	H1H2	=	"H1 > H2+δH";
	HPP	=	"Hnode > Htrig";
	HPM	=	"Hnode < Htrig".
d	Date of "Time", in yymmdd.		
e	Time of "Time", in hhmm.		
f	"Type of function" = "Constant"; new value.		
g	"δH"		
h	"Type of function" = "Timeseries"; "Time step" in minutes.		
i	1st value of "Timeseries".		
j	"reference node"		
k	"trigger level"		

5.7 RES

In the Flow Data - Result File the results from the flow calculation are printed. The concerned file is shown below. The name of the file is river.res.

```
VERSION FILE:  x.xx
ZOUT
C:\DUFLOW\RIEUT1\RIEUT1.CTR
C:\DUFLOW\RIEUT1\RIVER.NET
C:\DUFLOW\RIEUT1\RIVER.NOD
C:\DUFLOW\RIEUT1\RIVER.BND
C:\DUFLOW\RIEUT1\RIVER.BEG
C:\DUFLOW\RIEUT1\RIVER.RES
C:\DUFLOW\RIEUT1\RIEUT1.BNK
C:\DUFLOW\RIEUT1\RIEUT1.BEK
C:\DUFLOW\RIEUT1\EUTROF1.MOB
C:\DUFLOW\RIEUT1\RIEUT1.EXT
C:\DUFLOW\RIEUT1\RIEUT1.PRM
C:\DUFLOW\RIEUT1\RIEUT1.REK

ENDNAM
      0     288[a]    0      0      4[b]    5[c]    3[d]   600[e]    0      0
      0       4[b]    0      0      0       0       0       0        0      0
 910701[f]    0[g]
ENDIRO
  1[h]   SECT[i]  1[i]     1[j]    1[k]    2[l]   1000[m] -2.0000E+00[n] -2.0000E+00[o]
  2      SECT     2        2       2       3      1000    -2.0000E+00    -2.0000E+00
  3      SECT     3        3       3       4      1000    -2.0000E+00    -2.0000E+00
  4      SECT     4        4       4       5      1000    -2.0000E+00    -2.0000E+00
ENDADM
    0[p]  1[q]  0.0000E+00[r]  0.0000E+00[s]  1.0000E+00[t]  1.0000E+00[u]  0.0000E+00[v]
    0     2     0.0000E+00     0.0000E+00     1.0000E+00     1.0000E+00     0.0000E+00
    0     3     0.0000E+00     0.0000E+00     1.0000E+00     1.0000E+00     0.0000E+00
    0     4     0.0000E+00     0.0000E+00     1.0000E+00     1.0000E+00     0.0000E+00
    3     1     4.2339E-03     3.4274E-03     1.0000E+00     9.8963E-01     4.9646E-02
    3     2     3.4274E-03     2.6563E-03     9.8963E-01     9.9063E-01     4.9431E-02
    3     3     2.6563E-03     1.4502E-03     9.9063E-01     9.8502E-01     4.9340E-02
    3     4     1.4502E-03     0.0000E+00     9.8502E-01     9.8157E-01     4.9147E-02
    .     .         .              .              .              .              .
    .     .         .              .              .              .              .
  288     1     2.7949E-03     2.0971E-03     1.0000E+00     1.0000E+00     4.9939E-02
  288     2     2.0971E-03     1.3988E-03     1.0000E+00     1.0000E+00     4.9956E-02
  288     3     1.3988E-03     6.9971E-04     1.0000E+00     1.0000E+00     4.9974E-02
  288     4     6.9971E-04     0.0000E+00     1.0000E+00     1.0000E+00     4.9991E-02
```

The following list gives an explanation about the items in the file.

a	# Flow time steps
b	# Sections and structures.
c	# Nodes.
d	Ratio between Output time step and Flow time step.
e	Flow time step in seconds.
f	"Start of computation" (date) in yymmdd
g	"Start of computation" (time) in hhmm
h	Line number.
i	"Section/structure" name from the NET-file.
j	Section number (+300)
k	"Begin node" of the section.
l	"End node" of the section.
m	"Lenght" of the section
n	"Bottom level", begin.
o	"Bottom level", end.
p	Flow time step number.
q	Section number.
r	Water level at beginning of section.
s	Water level at end of section.
t	Discharge at beginning of section.

u	Discharge at end of section.
v	Velocity averaged over the section.

5.8 BEK

The Initial Conditions - Quality File for the project (appendix A) is shown below. In this file all of the data related to the quality model part are stored.

Below the initial condition quality file (RIEUT1.BEK) is shown , of the appendix A (EUTROF1).

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\RIEUT1.BEK
* Quality  Initial conditions      program version: x.xx
*
  1a a        b  2.0000c 2.0000d
  2 a          2.0000 2.0000
  3 a          2.0000 2.0000
  4 a          2.0000 2.0000
  1 bod        5.0000 5.0000
  :  :            :      :
  4 bod        5.0000 5.0000
  1 nh4        0.3000 0.3000
  :  :            :      :
  4 nh4        0.3000 0.3000
  1 no3        3.0000 3.0000
  :  :            :      :
  4 no3        3.0000 3.0000
  1 norg       0.8000 0.8000
  :  :            :      :
  4 norg       0.8000 0.8000
  1 o2         10.000 10.000
  :  :            :      :
  4 o2         10.000 10.000
  1 panorg     0.0400 0.0400
  :  :            :      :
  4 panorg     0.0400 0.0400
  1 porg       0.1100 0.1100
  :  :            :      :
  4 porg       0.1100 0.1100
  1 ss         5.0000 5.0000
  :  :            :      :
  4 ss         5.0000 5.0000
```

The following list gives explanation about the items in the file.

a	"Section/Structure number".
b	"Variable", name of the variable.
c	"Initial condition", at the begin of the section.
d	"Initial condition", at the end of the section.

Etc.

5.9 BNK

In the Boundary Conditions - Quality File all the boundary conditions related to the quality variables are stored.

Below is shown the boundary condition quality file (RIEUT1.BNK), of the appendix A (EUTROF1).

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\RIEUT1.BNK
* Quality  Boundary conditions      program version: x.xx
*
C   a                                       1b      a     c  1d
P   e1.9000f
C                                                   nh4      1
P    0.3000
C                                                   no3      1
P    3.0000
C                                                   norg     1
P    0.8000
C                                                   o2       1
P    10.000
C                                                   panorg   1
P    0.0400
C                                                   porg     1
P    0.1100
C                                                   ss       1
P    5.0000
C                                                   bod      1
P    5.0000
```

The following list gives explanation about the items in the file.

- a "Type";
  - C = "Concentration";
  - L =.."Load".
- b Condition number.
- c "Variable", selected from the picklist.
- d "Node(s)", number.
- e "Type of function" = "Constant".
- f Value for the "Variable".

5.10 EXT

In the External Variables File all xt external variables defined in the process description file are stored.

Below is shown the external variables file (RIEUT1.EXT), of the appendix A (EUTROF1).

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\RIEUT1.EXT
* Quality  External variables      program version: x.xx
*
XT  a                                               d      b  Ac
P   d100.00e
XT  a            60f910701g     0h                  i0     b  Ac
     0.0000i0.0000 0.0000 0.0000 0.0000 1.4562

       :      :      :      :      :      :
     67.974 38.922 11.989 0.0000 0.0000 0.0000j
XT                                                  nflux    A
P    0.0500
XT                                                  pflux    A
P    0.0050
XT                                                  resf     A
P    10.000
XT               60 910701      0                   t        A
     16.333 16.243 16.163 16.087 16.003 15.930
       :      :      :      :      :      :
     21.433 21.393 21.237 20.967 20.603 20.233
XT                                                  sod      A
P    1.0000
```

The following list gives an explanation about the items in the file.

- a "Type";
  - XT = Space and time depended external variable.
- b "External variable", name.
- c "Node(s)", number.

d "Type of function" = "Constant".
e Value of "External variable".
f "Time step", in minutes.
g "Start data", in yymmdd.
h "Start time", in hhmm.
i First value of "Timeseries".
j Last value of "Timeseries".

5.11 PRM

In the Parameter File all parameters defined in the process description file are stored.

Below is shown the parameter file (RIEUT1.PRM), of the appendix A (EUTROF1).

```
* DUFLOW data file :C: DUFLOW\RIEUT1 RIEUT1.PRM
* Quality  Parameters       program version: x.xx
*
achlc a     30.000b
anc          0.100
aoc          2.670
apc          0.010
e0           2.000
ealg         0.017
fdbod        1.000
fdnorg       0.400
fdporg       0.400
fnorg        0.600
fporg        0.600
is          80.000
kbod         0.180
kbodo        0.400
kden         0.090
kdie         0.200
kdno         0.100
kmin         0.200
kmn          0.025
kn           0.025
knit         0.090
kno          2.000
kp           0.005
kpip         0.010
kres         0.125
krmin        0.200
tbzv         1.050
tden         1.045
tga          1.060
tmin         1.080
tnit         1.080
tra          1.045
trea         1.040
umax         2.100
vso          0.500
vss          1.000
```

The following list gives an explanation of the items used in the file.

a "Name", parameter name in the process description file.
b Entered "VALUE".

5.12 REK

In the Quality Data - Result File (RIEUT1.REK) all the quality results are stored.

```
VERSION FILE:  x.xx
ZOUT
C:\DUFLOW\RIEUT1\RIEUT1.CTR
C:\DUFLOW\RIEUT1\RIVER.NET
C:\DUFLOW\RIEUT1\RIVER.NOD
C:\DUFLOW\RIEUT1\RIVER.BND
C:\DUFLOW\RIEUT1\RIVER.BEG
C:\DUFLOW\RIEUT1\RIVER.RES
C:\DUFLOW\RIEUT1\RIEUT1.BNK
C:\DUFLOW\RIEUT1\RIEUT1.BEK
C:\DUFLOW\RIEUT1\EUTROF1.MOB
C:\DUFLOW\RIEUT1\RIEUT1.EXT
C:\DUFLOW\RIEUT1\RIEUT1.PRM
C:\DUFLOW\RIEUT1\RIEUT1.REK

ENDNAM
       0       96[a]     0        0       4[b]     5[c]     1[d]  1800[e]    0        0
     12[f]      4[b]     0        0       0        0        0        0       0        0
 910701[g]      0[h]
ENDIR0
    1 a        mg-c/l     1
    2 bod      mg-o2/l    1
    3 nh4      mg-n/l     1
    4 no3      mg-n/l     1
    5 norg     mg-n/l     1
    6 o2       mg/l       1
    7 panorg   mg-p/l     1
    8 porg     mg-p/l     1
    9 chla                2
   10 fl                  2
   11 fn                  2
   12 ft                  2
ENDVAR
    1[i]   SECT[j]  1[j]     1[k]    1[l]    2[m]   1000[n] -2.0000E+00[o] -2.0000E+00[p]
    2      SECT     2        2       2       3      1000    -2.0000E+00    -2.0000E+00
    3      SECT     3        3       3       4      1000    -2.0000E+00    -2.0000E+00
    4      SECT     4        4       4       5      1000    -2.0000E+00    -2.0000E+00
ENDADM
      0[q]  1[r]  2.0000E+00[s]  2.0000E+00[t]  2.0000E+00[u]  2.0000E+00[v]  0.0000E+00[w]
      0     1     5.0000E+00     5.0000E+00     5.0000E+00     5.0000E+00     0.0000E+00
      0     1     3.0000E-01     3.0000E-01     3.0000E-01     3.0000E-01     0.0000E+00
      0     1     3.0000E+00     3.0000E+00     3.0000E+00     3.0000E+00     0.0000E+00
      0     1     8.0000E-01     8.0000E-01     8.0000E-01     8.0000E-01     0.0000E+00
      0     1     1.0000E+01     1.0000E+01     1.0000E+01     1.0000E+01     0.0000E+00
      0     1     4.0000E-02     4.0000E-02     4.0000E-02     4.0000E-02     0.0000E+00
      0     1     1.1000E-01     1.1000E-01     1.1000E-01     1.1000E-01     0.0000E+00
      0     1     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     1     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     1     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     1     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     2     2.0000E+00     2.0000E+00     2.0000E+00     2.0000E+00     0.0000E+00
      0     2     5.0000E+00     5.0000E+00     5.0000E+00     5.0000E+00     0.0000E+00
      0     2     3.0000E-01     3.0000E-01     3.0000E-01     3.0000E-01     0.0000E+00
      0     2     3.0000E+00     3.0000E+00     3.0000E+00     3.0000E+00     0.0000E+00
      0     2     8.0000E-01     8.0000E-01     8.0000E-01     8.0000E-01     0.0000E+00
      0     2     1.0000E+01     1.0000E+01     1.0000E+01     1.0000E+01     0.0000E+00
      0     2     4.0000E-02     4.0000E-02     4.0000E-02     4.0000E-02     0.0000E+00
      0     2     1.1000E-01     1.1000E-01     1.1000E-01     1.1000E-01     0.0000E+00
      0     2     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     2     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     2     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     2     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
      0     3     2.0000E+00     2.0000E+00     2.0000E+00     2.0000E+00     0.0000E+00
      0     3     5.0000E+00     5.0000E+00     5.0000E+00     5.0000E+00     0.0000E+00
      0     3     3.0000E-01     3.0000E-01     3.0000E-01     3.0000E-01     0.0000E+00
      0     3     3.0000E+00     3.0000E+00     3.0000E+00     3.0000E+00     0.0000E+00
      0     3     8.0000E-01     8.0000E-01     8.0000E-01     8.0000E-01     0.0000E+00
      0     3     1.0000E+01     1.0000E+01     1.0000E+01     1.0000E+01     0.0000E+00
      0     3     4.0000E-02     4.0000E-02     4.0000E-02     4.0000E-02     0.0000E+00
      0     3     1.1000E-01     1.1000E-01     1.1000E-01     1.1000E-01     0.0000E+00
```

```
 0   3   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   3   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   3   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   3   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   4   2.0000E+00   2.0000E+00   2.0000E+00   2.0000E+00   0.0000E+00
 0   4   5.0000E+00   5.0000E+00   5.0000E+00   5.0000E+00   0.0000E+00
 0   4   3.0000E-01   3.0000E-01   3.0000E-01   3.0000E-01   0.0000E+00
 0   4   3.0000E+00   3.0000E+00   3.0000E+00   3.0000E+00   0.0000E+00
 0   4   8.0000E-01   8.0000E-01   8.0000E-01   8.0000E-01   0.0000E+00
 0   4   1.0000E+01   1.0000E+01   1.0000E+01   1.0000E+01   0.0000E+00
 0   4   4.0000E-02   4.0000E-02   4.0000E-02   4.0000E-02   0.0000E+00
 0   4   1.1000E-01   1.1000E-01   1.1000E-01   1.1000E-01   0.0000E+00
 0   4   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   4   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   4   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 0   4   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
 1   1   1.9762E+00   1.9862E+00   1.9762E+00   1.9409E+00   0.0000E+00
 1   1   4.9974E+00   4.9977E+00   4.9974E+00   4.8835E+00   0.0000E+00
 1   1   3.0261E-01   3.0299E-01   3.0261E-01   2.9606E-01   0.0000E+00
 .   .       .            .            .            .            .
 .   .       .            .            .            .            .
96   4   6.0750E+01   6.1093E+01   0.0000E+00   0.0000E+00   0.0000E+00
96   4   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
96   4   9.0726E-01   9.0795E-01   0.0000E+00   0.0000E+00   0.0000E+00
96   4   1.1049E+00   1.1049E+00   0.0000E+00   0.0000E+00   0.0000E+00
```

The following list gives an explanation of the items used in the file.

a	# Flow time steps
b	# Sections and structures.
c	# Nodes.
d	Ratio between Output time step and Quality time step.
e	Quality time step in seconds.
f	# Output variables
g	"Start of computation" (date) in yymmdd
h	"Start of computation" (time) in hhmm

i	Line number.
j	"Section/structure" name from the NET-file.
k	Section number (+300)
l	"Begin node" of the section.
m	"End node" of the section.
n	"Lenght" of the section
o	"Bottom level", begin.
p	"Bottom level", end.

q	Quality time step number.
r	Section number.
s	Concentration value at beginning of section.
t	Concentration value at end of section.
u	Load value at beginning of section.
v	Load value at end of section.
w	Meaningless.

5.13 MSR

In the Measured Data File (MEASUR.MSR) the measured data can be stored. The file shown below is an example given of a measured value. Chosen is the variable ss, with a constant value of 10.000.

The format of this file is equal to that of the Boundary Condition File.

```
* DUFLOW data file :C:\DUFLOW\RIEUT1\MEASUR.MSR
* Measured data       program version: x.xx
*
C                                                      ss        5
F     10.000
```

6. Miscellaneous

6.1 DUFLOW Helpdesk

Users of DUFLOW can subscribe to the DUFLOW helpdesk. DUFLOW users may contact the helpdesk when encountering problems while using DUFLOW. When the user enrols a mistake, it will be solved as quickly as possible and the user will receive the latest update.

Users with a subscription to the helpdesk will receive a free update of the package at least once a year. In this manner, the user is assured of the corrections made in the new releases.

About once a year a DUFLOW users day is organised. During this activity users may present their results of using the DUFLOW package. This users day is particularly focused on the mutual acquaintance between users. Attendees of these days are informed about the latest DUFLOW developments.

6.2 Courses

Courses of DUFLOW are regularly organised by the IHE, which usually take place in the course of 2 to 5 days. The course is divided into the application of DUFLOW with respect to water quantity problems, water quality problems and the use of the precipitation runoff model in DUFLOW.

During the course, lectures concerning the theoretical background of the model are alternated by workshops. The purpose of the course for the user to become familiar with the DUFLOW package

7. Error-codes

In this chapter a list of possible errors are given which can occur during the calculation of DUFLOW. The explanation of the error is given with possible solution. If you have any questions about the working of the program, you can always consult the EDS Helpdesk (070-3014600).

7.1 Input errors

3001	Duplicate boundary condition.
3002	Missing quality condition.
3003	Quality boundary condition does not have a matching flow boundary condition.
3004	Missing Chezy value for elliptic culvert.
3014	Input error in calculation times.
3020	Error in given input file.
3023	Invalid node defined in Boundary Conditions File.
3024	Error in given input file.
3025	Invalid node number in Boundary Conditions File.
3026	Invalid sectoin number in Boundary Condition File.
3028	Defined node or section does not exist in string for output variables.
3029	Invalid section defined in Locations for Output.
3032	Missing parameter name or value.
3044	Invalid name of state variable in Initial Conditions File.
3048	Duplicate node number.
3049	Duplicate section number.
3052	Syntax error in given input file.
3055	Invalid name for a water state variable in the Boundary Conditions File.
3057	Invalid name for external variable in External Variables File.
3062	The dump file is not compatible with the quality model.
3063	The water levels in the definition of the cross sections are not ascending.

3064	The wet areas in the definition of the cross sections are not ascending.
3065	Given Chezy values are ambiguous.
3066	The given length of the section is less than or equal to zero.
3067	Error in the water level dependent data for the given section.
3070	Streaming widths and streaming areas are given at the same time for the given section number.
3071	Missing streaming areas or widths.
3072	The given streaming areas are ambiguous.
3073	The given streaming widths are ambiguous.
3074	Missing storage width for the given section number.
3075	The given storage widths are ambiguous.
3076	Not enough levels are given for the water level dependent data (must be at least 2).
3077	Incorrect number of levels given for some of the entries of the water level dependent data for the given section number.
3079	Invalid time given in timeseries.
3039	The levels defined for a QH-related boundary condition for the given node are not ascending.
3040	The number of levels defined for a QH-related boundary condition for the given node is not equal to the number of discharges.

7.2 Memory errors

3005	Not enough memory available.
3006	Internal memory error. Contact EDS.
3007	Internal memory error. Contact EDS.
3008	Internal memory error. Contact EDS.
3009	Internal memory error. Contact EDS.
3018	Internal memory error. Contact EDS.

7.3 Water quality model errors

3010	Error in water quality model containing powers (a^b).
3031	Non existing output variable in water quality model requested.
3033	Non existing parameter in the water quality model.
3045	Read error occurred while reading the Water Quality Model File, try compiling the Water Quality Model Definition File again.

7.4 Version errors

3011	Student version of DUFLOW, the total number of water and bottom variables is restricted.
3012	Student version of DUFLOW, the total number of sections and total number of nodes is restricted.

7.5 Errors on file

3013	Error while opening file for reading. File does not exist or is in use.
3015	Error while opening file for writing. File is in use or disk is full.
3016	Error while writing to file. File is already in use or disk is full. .
3021	Error while reading file. Unexpected end of file encountered.

7.6 Instability errors

3017	Flow computation has become unstable. Check model input for errors or possible instabilities.
3019	Pivot element in the node is zero. Possibly in this node only structures are defined and no ordinary sections, small ordinary section to this node. Otherwise the computation has become unstable, in that case check the output in this node.
3051	Negative storage area is computed at the given time step and section number. If this warning persists for other time steps, decrease the time step for flow or increase the threshold value for drying and flooding.

7.7 Read errors

3022	Error in Flow Boundary Condition File.
3035	Error in Quality Boundary Condition File.
3036	Error in Boundary Condition File.
3038	Error in Boundary Condition File.
3047	Error in Network File, section or node number of a section is less than zero.

7.8 Internal errors

3027	Internal error
3030	Internal error while reading MOB file. Contact EDS.
3037	Internal error, condition code does not exist in the file.
3041	Internal error while reading symbol table of the MOB file. Contact EDS.
3042	Internal error while reading symbol table of the MOB file. Contact EDS.
3043	Internal error while reading Water Quality Initial Conditions File. Contact EDS.
3046	Internal read error while reading the Network File. Contact EDS.
3050	Internal syntax error occurred in file. Contact EDS.
3053	Internal error, missing streaming areas for given section number. Contact EDS.
3054	Internal error, streaming areas and streaming widths are given simultaneously. Contact EDS.

3056 Internal read error while reading the Quality Boundary Conditions File. Contact EDS.

3058 Internal read error while reading the External Variables File. Contact EDS.

3059 Internal error while reading the Flow Initial Conditions File. Contact EDS.

3060 Internal error while reading elliptic culvert data. Contact EDS.

3061 Internal error, invalid character code found in the Network File. Contact EDS.

3068 Internal error while reading pump section data. Contact EDS.

3069 Internal error while reading siphon section data. Contact EDS.

3078 Internal error while reading data for given structure number. Contact EDS.

3080 Internal error while reading Fourier Timeseries in Boundary Condition File.

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9. Index

Appendix A Eutrof1

EUTROF1 is one of the two pre-defined eutrophication models included in DUFLOW. It is a relatively simple model based on the us epa model eutro4. It includes the cycling of nitrogen, phosphorus and oxygen. The growth of one phytoplankton species is simulated. The interaction between the sediment and the overlying water column is not included in a dynamic way. Sediment exchange fluxes of oxygen, ammonia and phosphorus can be specified by the user. These fluxes may be location specific and time dependent, reflecting temporal and seasonal variations.

The model is in particular suitable to study the short term behaviour of systems. For example to examine the impacts of a discharge on the oxygen dynamics, or to explore the effects of flushing on the chlorophyll-a concentration.

In case the long term functioning of a system is of interest the other pre-defined eutrophication model EUTROF2 is more appropriate. EUTROF2 includes three algal species, so succession can be simulated to a certain extend. Furthermore this model also describes the interactions between the sediment and the overlying water column.

A.1. State variables

Figure A-1 presents the principle kinetic interactions for the modelled state variables. The model includes the following state variables:

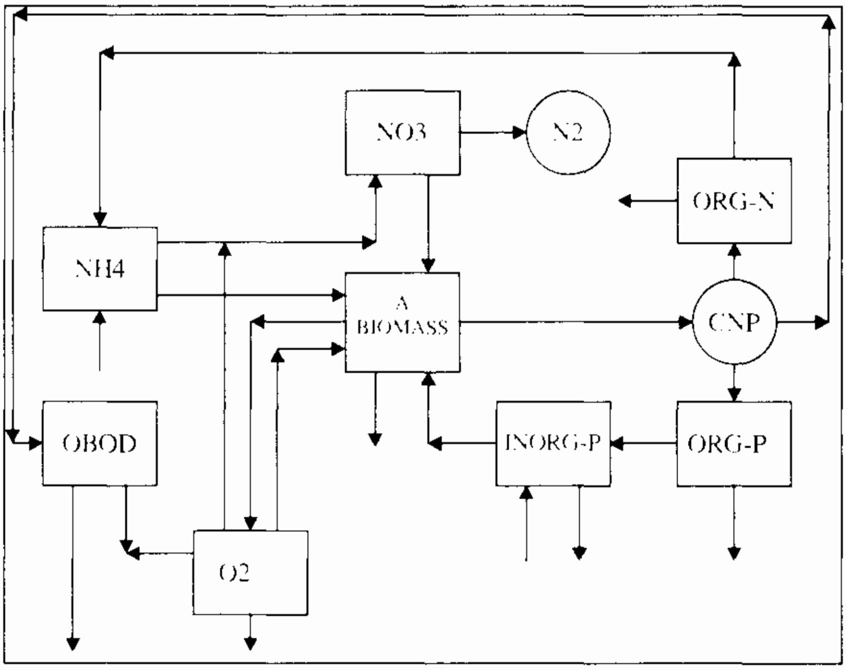
A	Algal Biomass (mg C/l)
Porg	Organic Phosphorus (mg P/l)
Pinorg	Inorganic Phosphorus (mg P/l)
Norg	Organic Nitrogen (mg N/l)
NH4	Ammonia Nitrogen (mg N/l)
NO3	Nitrate Nitrogen (mg N/l)
O2	Oxygen (mg O_2/l)
bod	Carbon 5 day Biochemical Oxygen Demand (mg O_2/l)
SS	Suspended Solids (mg/l)

Besides the state variables mentioned in figure A-1 a number of output variables are calculated:

Porto	Dissolved Inorganic Phosphorus (mg P/l)
Ptot	Total Phosphorus (mg P/l)
Nkj	Kjeldahl- Nitrogen (mg N/l)
Ntot	Total Nitrogen (mg N/l)

Chl-a Chlorophyll-a (Ug/l)

These variables are often monitored, so a direct comparison between measurements and simulated results is possible for these constituents.



Figuur A-1 EUTROF1 State variabele interactions

A.2. Process descriptions

In the following part the equations, describing the processes are presented. The explanation of the symbols used in this part is given in tables A-1 and A-2 at the end of Appendix A

- **Algae**

$$\frac{dA}{dt} = \left[\mu_{max} F_T F_N F_I\right]A - \left[k_{res}\theta_{ra}^{(T-20)} + k_{die}\right]A \qquad \text{(A-1)}$$

Algal growth is considered to be limited by nutrients, light and temperature. Nutrient limitation is described as:

$$F_N = \min\left[\frac{P_{ortho}}{P_{ortho} + K_P}, \frac{(NH_4 + NO_3)}{(NH_4 + NO_3) + K_N}\right] \qquad \text{(A-2)}$$

Which means that the reduction of the maximum growth rate is controlled by the most limiting factor. It is assumed that algae can use both ammonia and nitrate for their growth. The uptake of both nitrogen constituents is controlled by the ammonia preference factor (see eq. A-11).
Light limitation is described using the depth averaged Steele equation:

$$F_I = \frac{e}{\varepsilon_{tot} z}\left[\exp\left(-\frac{I_o}{I_s}\exp(-\varepsilon_{tot} z)\right) - \exp\left(-\frac{I_o}{I_s}\right)\right] \qquad \text{(A-3)}$$

in which:

$$\varepsilon_{tot} = \varepsilon_0 + \varepsilon_{alg} Chl - a + \varepsilon_{ss} SS \qquad \text{(A-4)}$$

Temperature dependency of the algal growth rate is given by:

$$F_T = \theta_{ga}^{(T-20)} \qquad \text{(A-5)}$$

Temperature dependency for all process rates is described in the same way as in eq. A-5. The rate constant at a reference temperature of 20 °C is multiplied with

a coefficient, determining the change per °C difference from the reference temperature.
Two terms describing the loss processes complete the algal balance equation. The first one describes the endogenous respiration, which is considered to be temperature dependent. The second is a lumped rate constant including death rate and the effect of grazing.

For internal computational purpose algal carbon is used as a measure for the biomass. The algal-C concentration is converted to chlorophyll-a using a fixed chlorophyll to carbon ratio.

- **Organic Phosphorus**

$$\frac{dP_{org}}{dt} = -k_{min}\theta_{min}^{(T-20)}P_{org} - \frac{v_{SO}}{z}(1-f_{dporg})P_{org}$$
$$+f_{porg}\left[k_{res}\theta_{ra}^{(T-20)} + k_{die}\right]a_{pc}A \qquad \text{(A-6)}$$

During the phytoplankton loss processes part of the associated phosphorus is released as organic phosphorus, the remaining part is distributed to the inorganic phosphorus pool. The phosphorus to carbon ratio is assumed to be constant. Due to mineralisation, organic phosphorus is converted to inorganic phosphorus. Mineralisation is described as a temperature dependent process. Part of the organic phosphorus is present in a particulate form and is subject to settling.

- **Inorganic Phosphorus**

$$\frac{dP_{anorg}}{dt} = -\frac{v_{SS}}{z}(1-f_{dpano})P_{anorg} + k_{min}\theta_{min}^{(T-20)}P_{org} - \mu_{max}F_T F_N F_I a_{pc}A$$

$$+(1-f_{porg})\left[k_{res}\theta_{ra}^{(T-20)} + K_{die}\right]a_{pc}A + \frac{P_{flux}}{z} \qquad \text{(A-7)}$$

Inorganic phosphorus will be formed during mineralisation of organic phosphorus and is also released during the algal respiration and die-off. Part of the inorganic phosphorus is adsorbed to the suspended solids. The dissolved fraction is calculated using:

$$f_{dpano} = \frac{1}{1+K_{pip}SS} \qquad \text{(A-8)}$$

The use of eq. A-8 implies that it is assumed that the equilibrium is reached instantaneously. The sorption rate is fast compared to most other relevant processes. Furthermore it is assumed that the linear part of the sorption isotherm may be used.

- **Organic Nitrogen**

$$\frac{dN_{org}}{dt} = -k_{min}\theta_{min}^{(T-20)}N_{org} - \frac{v_{so}}{z}(1-f_{dnorg})N_{org}$$
$$+f_{norg}\left[k_{res}\theta_{ra}^{(T-20)} + k_{die}\right]a_{nc}A \qquad \text{(A-9)}$$

Organic nitrogen is produced during respiration and die-off of algae. Like organic phosphorus part of the organic nitrogen is associated with particulate matter and will be subject to settling. Due to mineralisation organic nitrogen will be released as ammonia. De rate constant for the mineralisation of both organic nitrogen and phosphorus are assumed to be equal.

- **Ammonia Nitrogen**

$$\frac{dNH_4}{dt} = -k_{nit}\theta_{nit}^{(T-20)}\frac{O_2}{O_2+K_{NO}}NH_4 + k_{min}\theta_{min}^{(T-20)}N_{org} - \mu_{max}F_T F_N F_I a_n P_{NH4} A$$

$$+(1-f_{nwas})\left[k_{res}\theta_{res}^{(T-20)} + k_{die}\right]a_n A + \frac{N_{flux}}{z} \qquad \text{(A-10)}$$

During the algal respiration and die-off part of the nitrogen included in the biomass is released as ammonia. The remaining part is added to the pool of organic nitrogen. Both ammonia and nitrate can be used for algal growth.

The preference for the nitrogen source is controlled by the preference factor given by:

$$P_{NH4} = NH_4\frac{NO_3}{(K_{mN}+NH_4)(K_{mN}+NO_3)}$$

$$+NH_4\frac{K_{mN}}{(NH_4+NO_3)+(K_{mN}+NO_3)} \qquad \text{(A-11)}$$

The nitrification rate is controlled by the oxygen concentration, using a Monod type of equation. Depending on the value of K_{NO} the rate can be limited at low oxygen concentrations.

- **Nitrate Nitrogen**

$$\frac{dNO_3}{dt} = -k_{den}\theta_{den}^{(T-20)}\frac{K_{dNO}}{K_{dNO}+O_2}NO_3 + k_{nit}\theta_{nit}^{(T-20)}\frac{O_2}{O_2+K_{NO}}NH_4$$

$$-\mu_{max}F_T F_N F_I a_n(1-P_{NH4})A \qquad \text{(A-12)}$$

Nitrate is formed during nitrification. Depending on the ammonia preference factor, nitrate can be used for algal growth. Denitrification, which is also controlled by the oxygen concentration is included too.

- **BOD 5**

$$\frac{dBOD}{dt} = -k_{BOD}\theta_{BOD}^{(T-20)}\frac{O_2}{O_2+K_{BODO}}BOD - \frac{v_s}{z}(1-f_{dBOD})BOD$$

$$\left[+k_{die}a_{oc}A - \frac{5}{4}\frac{32}{14}k_{den}\theta_{den}^{(T-20)}\frac{K_{dNO}}{K_{dNO}+O_2}\right]X_{conv} \qquad \text{(A-13)}$$

Eq. A-13 describes the 5 day carbon BOD, which is also used for input. In the oxygen balance equation (eq. A-15) the ultimate bod is used. A conversion factor is used to calculate BOD_5 from bodu. The bod, which is produced by die off of the algae is converted to BOD_5. Also the bod used as a carbon source during denitrification is corrected this way.

$$X_{conv} = 1 - \exp\left(-5k_{BOD}^{20}\right) \qquad \text{(A-14)}$$

Part of the BOD is in a particulate form and will settle. The oxidation of BOD is temperature dependent and is limited at low oxygen concentrations by a Monod type of kinetic.

- **Oxygen**

$$\frac{dO_2}{dt} = k_{re}\theta_{re}^{(T-20)}(c_s - O_2) - k_{BOD}\theta_{BOD}^{(T-20)}\frac{O_2}{O_2+K_{BODO}}\frac{BOD}{X_{conv}}$$

$$-\frac{64}{14}k_{nit}\theta_{nit}^{(T-20)}\frac{O_2}{O_2+K_{NO}}NH_4 - \frac{32}{12}k_{res}\theta_{res}^{(T-20)}A - \frac{SOD}{z}$$

$$+\mu_{max} F_T F_N F_l A(\frac{32}{12} + \frac{48}{14} a_{nc} (1 - P_{NH4}) NO_3) \qquad \text{(A-15)}$$

The mass transfer coefficient for oxygen is given by the following empirical equation:

$$k_{mas} = 3.94 u^{0.5} z^{-1.5} \qquad \text{(A-16)}$$

or if $k_{mas} < k_{rmin}$:

$$k_{mas} = k_{rmin} \qquad \text{(A-17)}$$

The dimension of the velocity is m/s and the resulting k_{mas} is in m/day. At low stream velocity the use of eq. A-16 can result into extremely low value for the mass transfer coefficient. The user can define a minimum value for k_{mas}, which is used as a lower bound for the mass transfer coefficient. The reaeration rate constant kre is given by:

$$k_{re} = \frac{k_{mas}}{z} \qquad \text{(A-18)}$$

The oxygen saturation concentration is also calculated, using an empirical equation:

$$C_S = 14.5519 - 0.373484T + 0.005016 07T^2 \qquad \text{(A-19)}$$

Additional to the oxidation of carbon bod the following oxygen consuming processes are included in the oxygen mass balance equation: the algal respiration, nitrification and the sediment oxygen demand. sod can be supplied by the user as a time dependent and location specific function, in order to simulate seasonal and temporal variations. Production of oxygen results from primary production. In case nitrate is used as a source for nitrogen an additional oxygen production takes place, because of the reduction of nitrate during the assimilation process.

- **Suspended Solids**

$$\frac{dSS}{dt} = -\frac{v_{SS}}{z} SS + \frac{\Phi_{res}}{z} \qquad \text{(A-20)}$$

Sedimentation is described as a first order process. The resuspension process is not modelled. The resuspension flux should be supplied by the user. It can be entered as a time dependent input variable. The choice of the resuspension flux and the settling velocity governs the level of suspended solids in the water column, which is important for the distribution of inorganic phosphorus between the dissolved and particulate phases (see eq. A-8)

- **Output Variables**

In order to make direct comparison of the results with frequently monitored variables more convenient, the following output variables are calculated.

$$P_{orto} = P_{anorg} f_{dpano} \qquad \text{(A-21)}$$

$$P_{tot} = P_{org} + P_{anorg} + Aa_{pc} \qquad \text{(A-22)}$$

$$N_{kj} = N_{org} + NH_4 + Aa_{nc} \qquad \text{(A-23)}$$

$$N_{tot} = N_{kj} + NO_3 \qquad \text{(A-24)}$$

$$Chl - a = a_{chlc} A \qquad \text{(A-25)}$$

A.3. Parameters

Table A-1 presents a list of all parameters used in EUTROF1. In these table also the default values used and a typical range for some parameters is given.

Symbol	Description	Dimension	Default	Range
a_{chl}	Chlorophyll to carbon ratio	µg Chl-a/mg C	30	25-250
a_{nc}	Nitrogen to carbon ratio	mg N/mg C	0.25	0.18-0.25
a_{oc}	Oxygen to carbon ratio	mg O_2/mg C	2.67	
a_{pc}	Phosphorus to carbon ratio	mg P/mg C	0.025	0.025-0.050
ε_0	Background extinction	1/m	1.0	1.0-5.0
ε_{alg}	Specific extinction chlorophyll	µg Chl-a/l.m	0.016	0.012-0.025
ε_{SS}	Specific extinction suspended solids	mg SS/l.m	0.050	0.020-0.060
f_{dbod}	Fraction dissolved BOD	-.	1	
f_{dnorg}	Fraction dissolved organic nitrogen	-.	0	
f_{dporg}	Fraction dissolved organic phosphorus	-.	0	
f_{norg}	Fraction algal nitrogen released as NORG	-.	1	
f_{porg}	Fraction algal phosphorus released as PORG	-.	1	
I_s	Optimal light intensity	W/m^2	40	10-100
k_{BOD}	Oxidation rate constant BOD	1/d	0.1	0.02-3.4
K_{BODO}	Monod constant oxidation BOD	mg O_2/l	2.0	
k_{den}	Denitrification rate constant	1/d	0.1	0.0-0.1
K_{dNO}	Monod constant denitrification	mg O_2/l	0.5	
k_{min}	Mineralisation rate constant	1/d	0.1	0.01-0.40
K_{mN}	Ammonia preference constant	mg N/l	0.025	
K_N	Monod constant nitrogen	mg N/l	0.010	0.01-0.30
k_{nit}	Nitrification rate constant	1/d	0.1	
K_{NO}	Monod constant nitrification	mg O_2/l	2.0	
K_P	Monod constant phosphorus	mg P/l	0.005	0.001-0.05
K_{pip}	Partition constant phosphorus	l/ mg SS	0.010	
k_{res}	Respiration rate constant	1/d	0.1	0.05-0.2
k_{rmin}	Minimum oxygen transfer coefficient	m/d	0.1	
k_{die}	Die rate constant	1/d	0.2	0.0-0.3
θ_{BOD}	Temperature coefficient oxidation BOD	-	1.047	
θ_{den}	Temperature coefficient denitrification	-	1.045	
θ_{ga}	Temperature coefficient algal growth	-	1.047	
θ_{min}	Temperature coefficient mineralisation	-	1.047	
θ_{nit}	Temperature coefficient nitrification	-	1.080	
θ_{ra}	Temperature coefficient respiration	-	1.047	

θ_{rea}	Temperature coefficient reaeration	-	1.024	
μ_{max}	Maximum specific growth rate algae	1/d	4.0	1.0-5.0
v_{so}	Nett settling velocity organic matter	m/d	0.1	0.001-0.1
v_{ss}	Settling velocity suspended solids	m/d	0.1	0.1-5.0

Table A-1 Parameters used in EUTROF1

A.4. External variables

Table A-2 presents the external variables used in the model. All input variables mentioned in this table are location specific and time dependent. For some of the variables a typical range is provided. For the surface light intensity and the temperature an example time series is given on the diskette. These series represent actual measured data during a summer month at moderate latitude and can be found in the in the file RIEUT1.EXT.

Symbol	*Description*	*Dimension*	*Default*	*Range*
SOD	Sediment oxygen demand	g O_2/m^2,d	1.00	0.0-2.0
Pflux	Phosphorus release flux	g P/m^2,d	0.00	0.0-0.01
Nflux	Ammonia release flux	g N/m^2,d	0.00	0.0-0.05
Φres	Resuspension flux suspended solids	g/m^2,d	0.50	0.0-3.0
I_0	Surface light intensity	W/m^2	10.0	
T	Temperature	°C	20.0	

Table A-2 External variables used in EUTROF1

A.5. Flow variables

The velocity is calculated from the flow and the cross sectional area, which are defined as flow variables. This means that they are read directly from the hydrodynamic part of DUFLOW.

Symbol	Description	Dimension	Default
Q	Flow	m^3/s	1.00
As	Cross sectional area	m^2	10.0
z	Depth	m	1.00

Table A-3 Flow variables used in EUTROF1

Appendix B Eutrof2

Like the other pre-defined model EUTROF2 is a eutrophication type of model. The main difference between this model and EUTROF1 is the way the sediment water interaction is dealt with. In this model the sediment top layer is modelled to, which enables a dynamic description of the fluxes across the sediment water interface. As the sediment act as the memory of a system with respect to the loading history, this makes the model especially suitable for simulation of longer time scales. EUTROF2 can be used for example to study the effects of reduction in nutrient loads upon the release of nutrients from the sediment.

The water column kinetics are very similar to those used in EUTROF1. Also in this model the cycling of nitrogen, oxygen and phosphorus is modelled. However in EUTROF2 three types of algal species can be defined, which means that also succession and the dynamics of the composition of the algal population can be simulated to a certain extend.

B.1. State variables

The following state variables are included in the model:

A_1,A_2,A_3	Algal Biomass species 1,2 and 3 (mg C/l)
A_b	Total Algal Biomass in the sediment (mg C/l)
SS_W	Suspended Solids concentration (mg/l)
SS_B	Solid concentration in the sediment (mg/l)
TIP_W	Total inorganic phosphorus water column (mg P/l)
TIP_B	Total inorganic phosphorus sediment (mg P/l)
TOP_W	Total organic phosphorus water column (mg P/l)
TOP_B	Total organic phosphorus sediment (mg P/l)
TON_W	Total organic nitrogen (mg N/l)
TON_B	Total organic nitrogen sediment (mg/N/l)
$NH4_W$	Ammonia nitrogen water column (mg N/l)
$NH4_B$	Ammonia nitrogen sediment (mg N/l)
$NO3_W$	Nitrate nitrogen water column (mg N/l)
$NO3_B$	Nitrate nitrogen sediment (mg N/l)
$O2_W$	Oxygen water column (mg/l)
$O2_B$	Oxygen sediment (mg/l)
BOD_W	Biochemical oxygen demand (mg/l)
BOD_B	Biochemical oxygen demand (mg/l)

B.2. Sediment model

The degradation of organic matter in the sediment can have an important influence on the concentration of oxygen and nutrients in the overlying water column. Due to the decomposition of organic matter nutrients are released to the interstitial water in the sediment. Furthermore the degradation of organic matter within the sediment results into a flux of oxygen from the overlying water to the sediment (or a flux of oxygen equivalents directed towards the water column in case of anaerobic degradation). This *sediment oxygen demand* can be a substantial sink for oxygen, while the resulting release of nutrients can be an important contribution to the total nutrient load of a system. Additionally the occurrence of anoxic conditions within the sediment may dramatically increase certain nutrient fluxes. Complex mechanisms of redox reactions and pH control the state and concentration of nutrients and metals and thereby the release of nutrients from the sediment. The relative importance of the sediment water interaction requires the incorporation of a dynamic description of the processes within the sediment and of the transport across the sediment water interface. There are several ways to model the sediment water interaction. In EUTROF2 a relative simple description is used. A general outline of the concept used is given in this paragraph. In the next paragraph a more detailed description of the processes in both the water column and the sediment is presented.

Like in eutrof1 suspended solids are modelled is a simple way. Sedimentation is considered to be a first order process. The resuspension flux should be provided by the user. Eventually the resuspension flux can be related to flow velocity or bottom shears stress. Such relationships however are not included in the process descriptions because several relationships are available and the user should select the one most appropriate for the water system to be modelled. Sedimentation and resuspension are assumed to occur simultaneously. The following equation describes the suspended solids concentration in the water column:

$$\frac{dSS_W}{dt} = \frac{v}{Z} + \frac{F_{res}}{Z} \qquad \text{(B-1)}$$

As the porosity and density of the sediment top layer are considered to be constant and only one fraction suspended solids is taken into account the concentration of sediment is constant and given by:

$$SS_B = \rho * (1 - POR) * 1000 \qquad \text{(B-2)}$$

Because of the sedimentation and resuspension, the sediment water interface is moving with respect to the fixed coordinate system. The velocities by which the benthic surface is displaced can be expressed in terms of the sedimentation and resuspension fluxes:

$$v_s = -\frac{F_{sed}}{\rho * (1 - POR) * 1000} \qquad \text{(B-3)}$$

$$v_r = \frac{F_{res}}{\rho * (1 - POR) * 1000} \qquad \text{(B-4)}$$

In which the sedimentation flux F_{sed} is given by:

$$F_{sed} = v_{ss} * SS_W \qquad \text{(B-5)}$$

The net displacement of the interface is given by:

$$v_{sd} = v_s - v_r \qquad \text{(B-6)}$$

Because the depth of the sediment top layer is considered to be constant the interface between the sediment top and lower layer is also moving with a velocity equal to v_{sd}.

The equations B-1 to B-6 form the basis of the dynamic description of the sediment water interactions. The concept is illustrated in figure B-1.

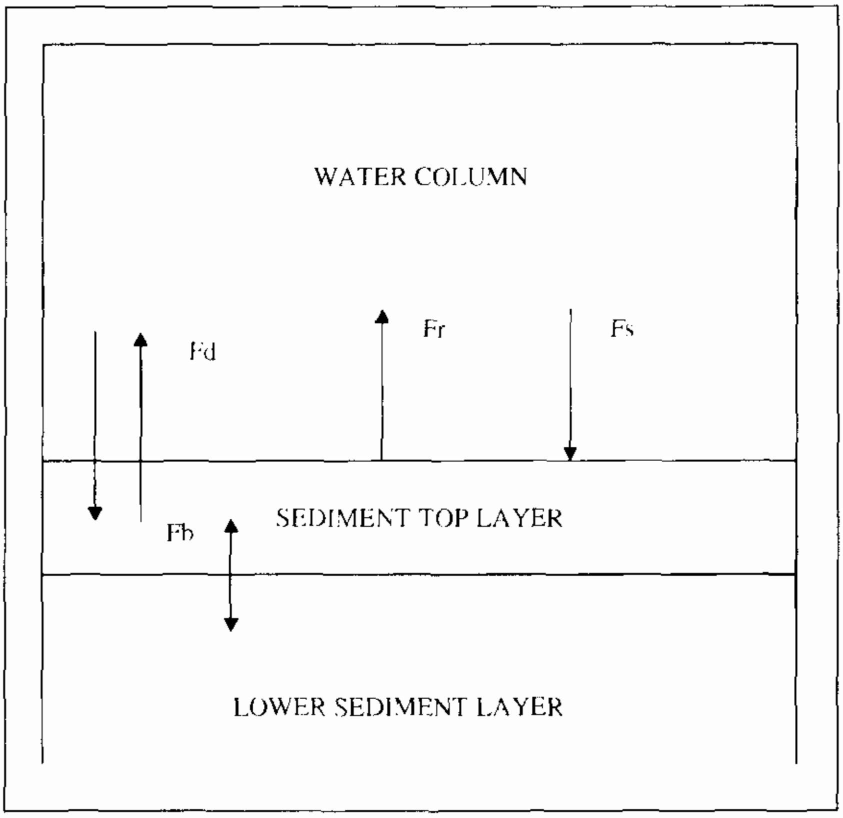


Figure B-1 Sediment model concept

For the description of the exchange fluxes a distinction must be made between dissolved constituents (like ammonia, nitrate and oxygen) and constituent which can be associated with the suspended solids (like inorganic and organic phosphorus, organic nitrogen and bod). These last type of constituents are considered to be present both in a dissolved and particulate form. For a certain constituent X the following forms are distinguished:

$$DX_W = f_{dxw} TX_W \tag{B-7}$$

$$PX_W = \left(1 - f_{dxw}\right)\frac{TX_W}{SS_W} \tag{B-8}$$

$$DX_B = f_{dxb}\frac{TX_W}{POR} \tag{B-9}$$

$$PX_B = \left(1 - f_{dxb}\right)\frac{TX_B}{SS_B} \tag{B-10}$$

Where TX_W and TX_B are the total concentrations of constituent X in the water column and the sediment top layer respectively. DX and PX represent the dissolved and particulate fractions. The total sediment concentration is expressed per unit of sediment volume. The dissolved fractions in the water column and sediment are considered to be constant and given by f_{dxw} and f_{dxb}. For inorganic phosphorus these fractions are calculated using linear partition (see eq. B-36 and B-37). The concentration of dissolved constituents in the sediment is expressed per unit of pore water volume and the particulate constituent concentration are given per unit of dry sediment weight in both the water column and sediment top layer.

The total exchange of constituent X across the sediment water interface is represented by the following fluxes:

- **The diffusive exchange flux:**

$$F_{XD} = \frac{E_{diff}}{HB} \left(D_{XB} - D_{XW} \right) \tag{B-11}$$

The dissolved fraction is subject to diffusive exchange. The difference between the concentration in the interstitial water and the water column is the driving force for mass transport.

- **The sedimentation flux:**

$$F_{XS} = F_{sed} PX_W + v_s \; POR \; DX_W \tag{B-12}$$

As the particulate fraction is expressed per unit of sediment mass, the flux of constituent X across the interface is equal to the sedimentation flux of suspended solids multiplied with the particulate constituent concentration. The second term in eq. B-12 describes the inclusion of pore water due to the formation of new sediment by sedimentation.

- **The resuspension flux:**

$$F_{XR} = F_{res} PX_B + v_r \; POR \; DX_B \tag{B-13}$$

The resuspension of particulate X is given by the product of the resuspension flux of solids and the particulate concentration in the sediment. The second term of eq. B-13 represents the release of pore water during resuspension.

- **Transport between top and lower sediment layer:**

$$F_{XB} = -v_{sd} TX_B \qquad if \; v_{sd} < 0 \tag{B-14}$$

or:

$$F_{XB} = -v_{sd} TX_{LB} \qquad if \; v_{sd} < 0 \tag{B-15}$$

Because of the concept of a constant top layer depth there is a transport of sediment between the top and lower sediment layer if the net displacement velocity v_{sd} is not equal to 0. If net sedimentation occurs sediment is transported from the top toward the lower layer. In case of net resuspension the sediment top layer is replenished with sediment from the lower layer. The concentration in the lower sediment layer is considered to be constant and should be supplied by the user. Diffusive exchange between the two sediment layers is not taken into account. Hence the concentration in the top layer is only influenced by the quality of the lower layer if net resuspension occurs.

The total transport across the interface is equal to the sum of the fluxes expressed above. The equations describing the concentration in the water column and the sediment top layer are given by:

$$\frac{dX_W}{dt} = \frac{F_{XD} - F_{XS} + F_{XR}}{Z} + P_{XW} \tag{B-16}$$

and:

$$\frac{dX_B}{dt} = \frac{F_{XD} - F_{XS} + F_{XR} + F_{XB}}{HB} + P_{XB} \tag{B-17}$$

Equations B-16 and B-17 also can be used for constituents only present in a dissolved form. For these constituents the individual fluxes can be expressed like:

$$F_{XD} = \frac{E_{diff}}{HB} \left(X_I - X_W \right) \tag{B-18}$$

$$F_{XS} = v_s\, POR\, X_W \qquad \text{(B-19)}$$

$$F_{XR} = v_r\, POR\, X_I \qquad \text{(B-20)}$$

$$F_{XB} = -v_{sd} X_B \quad if\ v_{sd} > 0 \qquad \text{(B-21)}$$

or

$$F_{XB} = v_{sd} X_{LB} \quad if\ v_{sd} < 0 \qquad \text{(B-22)}$$

The concentration in the interstitial water in this case is represented by X_I and equal to X_B/POR. For dissolved constituents the concentration in the interstitial is also influenced by sedimentation and resuspension, because of the inclusion or release of pore water respectively.

B.3. Process descriptions

In the following part the equations, describing the processes are presented. For each state variable the processes in both the sediment and the water column are given. The transport fluxes across the water sediment interface already have been described in eq. B-16 and B-17 and are not included in the equations below. The explanation of the symbols used in this part is given in the tables at the end of this appendix.

- **Algae**

In this model three algae species can be simulated. So the succession and dynamics of the composition of the algae population can be simulated to a certain extend.

The overall growth equation for each species is given by:

$$\frac{dA_{W,i}}{dt} = [\mu_{\max,i} F_{T,i} F_{N,i} F_{L,i}] A_{W,i} - [K_{die,i} + k_{res,i} \theta_{ra,i}^{(T-20)} - \frac{v_{sa,i}}{Z}] A_{w,i} \qquad \text{(B-23)}$$

The growth is considered to be limited by nutrients, light and temperature.

Nutrient limitation is described as:

$$F_{Ni} = \min\left[\frac{DIP_W}{DIP_W + k_p i}, \frac{DIN_W}{DIN_W + k_{ni}}\right] \qquad \text{(B-24)}$$

Where DIN_W is the total inorganic nitrogen concentration equal to the sum of nitrate and ammonia in the water column. The reduction of the maximum growth rate is controlled by the most limiting factor. It is assumed that algae can use both ammonia and nitrate for their growth. The uptake of both nitrogen constituents is controlled by the ammonia preference factor (see eq. B-40).

Because EUTROF2 is intended for simulation of long time scales a daily averaged light limitation function is used. The depth integrate Steele equation (see Appendix A, eq. A-3) is integrated over the daylight period. This means that EUTROF2 is not able to describe diurnal variations in algal growth. The light limitation factor is expressed as:

$$F_{Li} = \frac{e f}{\varepsilon_{tot} Z}\left[\exp(-\alpha_{1i}) - \exp(-\alpha_{0i})\right] \qquad \text{(B-25)}$$

in which:

$$\alpha_{0i} = \frac{I_a}{I_{si}} \qquad \text{(B-26)}$$

and:

$$\alpha_{1i} = \alpha_{0i} \exp(-\varepsilon_{tot} Z) \qquad \text{(B-27)}$$

I_a is the average light intensity during the daylight period (L) and f is the fraction of daylight during the day (equal to L/24).

The total extinction coefficient is determined by the background extinction of the water and the contributions of chlorophyll and suspended solids to the vertical light attenuation.

$$\varepsilon_{tot} = \varepsilon_{0} + \varepsilon_{alg} Chl - a + \varepsilon_{SS} SS \qquad \text{(B-28)}$$

For internal computational purpose algal carbon is used as a measure for the biomass. The algal C concentration is converted to chlorophyll-a using a fixed chlorophyll to carbon ratio for each species. The total chlorophyll concentration can be expressed as:

$$Chl - a = \sum_{i=1}^{3} a_{Chla - i} A_{Wi} \qquad \text{(B-29)}$$

Temperature dependency of algal growth is described in a different way as in EUTROF1. For the individual species an optimum curve is used to simulated temperature dependent growth. The temperature limitation factor is given by:

$$F_{Ti} = \frac{T_{cri} - T}{T_{cri} - T_{opi}} \exp\left(1 - \frac{T_{cri} - T}{T_{cri} - T_{opi}}\right) \qquad \text{(B-30)}$$

If the water temperature is above the critical temperature for growth

$F_{Ti} = 0$.

Three loss processes are included in the algal balance equation (eq. B-23). The endogenous respiration is considered to be temperature dependent. The second loss term represents the die-off and the effects of grazing and is regarded to be constant. Finally the sedimentation of algae is included. Although the sedimentation velocity of the algae is low, the total load settling to the sediment can be substantial. Together with the sedimentation of dead organic matter (detritus and from man made sources) it determines the organic and nutrient load of the sediment and controls the resulting interaction between the sediment and the overlying water column. Once settled into the sediment the algae are converted to benthic organic carbon and subject to anaerobic decomposition. There is no transport of living algae from the sediment to the water column. As the stoichiometric ratio for all algae species are considered to be the same for the benthic algal carbon concentration only one state variable has to be defined. The following equation is used to describe the algae concentration in the sediment:

$$\frac{dA_B}{dt} = -K_{daB} \theta_{daB}^{(T-20)} A_B \qquad \text{(B-31)}$$

- **Organic Phosphorus**

During respiration and die-off of the algae, part the associated phosphorus is released as organic phosphorus, the remaining part is distributed to the inorganic phosphorus pool. The phosphorus to carbon ration is assumed to be constant and the same for all three algae species. Due to aerobic mineralisation in the water column organic phosphorus is converted to the inorganic form. Organic phosphorus is both present in a dissolved and particulate form. The dissolved fraction is assumed to be constant and equal to f_{dpoW}. The following equation is used to describe the total organic phosphorus concentration in the water column:

$$\frac{dTOP_W}{dt} = -K_{min} \theta_{min}^{(T-20)} TOP_W + f_{porg} a_{pc} \sum_{i=1}^{3} \left[(K_{dai} + K_{resi} \theta_{resi}) A_{Wi} \right] \qquad \text{(B-32)}$$

In the sediment organic phosphorus is only subject to anaerobic decomposition. The total organic phosphorus in the sediment top layer is given by:

$$\frac{dTOP_B}{dt} = -K_{\min B}\theta_{\min B}^{(T-20)}TOP_B + a_{pc}K_{daB}\theta_{daB}^{(T-20)}A_B \qquad \text{(B-33)}$$

- **Inorganic Phosphorus**

The equations describing the inorganic phosphorus concentration in the water column and the sediment top layer are given by:

$$\frac{dTIP_W}{dt} = K_{\min}\theta_{\min}^{(T-20)}TOP_W - a_{pc}\sum_{i=1}^{3}\left[\mu_{\max i}F_{Ti}F_{Ni}F_{Li}A_{Wi}\right]$$

$$+(1-f_{porg})a_{pc}\sum_{i=1}^{3}\left[(K_{diei} + K_{resi}\theta_{rai}^{(T-20)})A_{Wi}\right] \qquad \text{(B-34)}$$

and:

$$\frac{dTIP_B}{dt} = K_{\min B}\theta_{\min B}^{(T-20)}TOP_B \qquad \text{(B-35)}$$

Inorganic phosphorus is formed during aerobic and anaerobic mineralisation in the water column and sediment respectively. It is also released during the algal respiration and die-off. Part of the inorganic phosphorus is adsorbed to the suspended solids. The dissolved fractions in the water column and in the interstitial water are calculated, using linear partition:

$$f_{dpW} = \frac{1}{1 + K_{pipW}SS_W} \qquad \text{(B-36)}$$

$$f_{dpB} = \frac{1}{1 + K_{pipB}SS_B} \qquad \text{(B-37)}$$

The use of equations B-36 and B-37 implies that is assumed that the equilibrium is reached instantaneously. The sorption rate is considered to be fast compared to the other relevant processes in the phosphorus cycle. Furthermore it is assumed that the linear part of the sorption isotherm may be used.

- **Organic Nitrogen**

The behaviour of organic nitrogen is similar to that of organic phosphorus. In the water column release during algal loss processes and anaerobic mineralisation takes place. In the sediment the anaerobic mineralisation of settled algae and organic nitrogen are the controlling processes. The total organic nitrogen concentration in the water column and sediment top layer are given by:

$$\frac{dTON_W}{dt} = -K_{\min}\theta_{\min}^{(T-20)}TON_W + f_{norg}a_{nc}\sum_{i=1}^{3}\left[(K_{die,i} + K_{res,i}\theta_{ra,i})A_{Wi}\right] \qquad \text{(B-38)}$$

$$\frac{dTON_B}{dt} = -K_{\min B}\theta_{\min B}^{(T-20)}TON_B + a_{nc}K_{daB}\theta_{daB}^{(T-20)}A_B \qquad \text{(B-39)}$$

- **Ammonia Nitrogen**

During algal respiration and die-off of the algae part of the nitrogen is released as ammonia. The remaining part is added to the pool of organic nitrogen. Both ammonia and nitrate can be used for algal growth. The preference for the nitrogen source used is controlled by the nitrogen preference factor given by:

$$P_{NH4} = NH4_W \frac{NO3_W}{(K_{mN} + NH4_W)(K_{mN} + NO3_W)}$$

$$+NH4_W \frac{K_{mN}}{(NH4_W + NO3_W)(K_{mN} + NO3_W)} \qquad \text{(B-40)}$$

The nitrification rate in the water column is controlled by the oxygen concentration, using a Monod type of equation. Depending on the value of K_{NO} the rate can be limited at low oxygen concentrations. The equation for ammonia nitrogen in the water column is given by:

$$\frac{dNH4_W}{dt} = -K_{nit}\theta_{nit}^{(T-20)} \frac{O2_W}{(O2_W + K_{no})} NH4_W + K_{min}\theta_{min}^{(T-20)} TON_W$$

$$-a_{nc} P_{NH4} \sum_{i=1}^{3} \left[\mu_{max,i} F_{Ti} F_{Ni} F_{Li} A_{Wi} \right] + a_{nc} \sum_{i=1}^{3} \left[K_{d,i} + K_{r,i}\theta_{ral}^{(T-20)} \right] \qquad \text{(B-41)}$$

Organic nitrogen is hydrolysed to ammonia by bacterial action within the sediment. As the decomposition processes in the bottom are considered to be anaerobic, it is assumed that there is no oxygen in the sediment top layer. Hence no nitrification occurs in the sediment. The equation describing the sediment ammonia concentration is given by:

$$\frac{dNH4_B}{dt} = K_{min}\theta_{min}^{(T-20)} TON_B \qquad \text{(B-42)}$$

- **Nitrate Nitrogen**

In the water column nitrate is formed during nitrification. Depending on the ammonia preference factor nitrate can be used as a nitrogen source for algal growth. Denitrification, which is also controlled by the oxygen concentration is included too. The nitrate concentration in the water column is given by:

$$\frac{dNO3_W}{dt} = -K_{den}\theta_{den}^{(T-20)} \frac{K_{dno}}{(K_{dno} + O2_W)} NO3_W$$

$$+K_{nit}\theta_{nit}^{(T-20)} \frac{O2_W}{(O2_W + K_{no})} NH4_W - a_{nc}(1 - P_{NH4}) \sum_{i=1}^{3} \left[\mu_{max,i} F_{Ti} F_{Ni} F_{Li} A_{Wi} \right]$$

(B-43)

In the bottom the only process is denitrification. Nitrate is present in the sediment due to the diffusive transport from the overlying water column. The nitrate concentration in the sediment top layer is given by:

$$\frac{dNO3_B}{dt} = -K_{denB}\theta_{denB}^{(T-20)} NO3_B \qquad \text{(B-44)}$$

- **Cbod**

Because in practice 5 day carbon bod values are used, the equation describing the BOD concentration are expressed in BOD_5. In the oxygen balance equation (eq. B-48) however the ultimate BOD is used. A conversion factor is used to calculate BOD_5 from BOD_u. The BOD, which is produced by die-off of the algae and the BOD used as a carbon source during denitrification is corrected using this conversion factor. The conversion factor is given by:

$$X_{conv} = 1 - \exp(-5K_{bod}^{20}) \tag{B-45}$$

The oxidation of BOD in the water column is temperature dependent and limited at low oxygen concentration by a Monod type of kinetic.

Water column BOD_5 is given by:

$$\frac{dBOD_W}{dt} = -K_{bod}\theta_{bod}^{(T-20)} \frac{O2_W}{(O2_W + K_{bodo})} BOD_W$$

$$+\left[a_{oc} \sum_{i=1}^{3} \left[K_{die,i} A_{Wi}\right] - \frac{5}{4}\frac{32}{14} K_{den}\theta_{den}^{(T-20)} \frac{K_{dno}}{(K_{dno} + O2_W)} NO3_W \right] X_{conv} \tag{B-46}$$

In the sediment the settled algae and benthic organic matter are subject to anaerobic degradation. In reality the reaction mechanisms involved are very complex. In the model only the initial step in which the organic carbon is converted to reactive intermediates is included. This formulation is similar and consistent with the degradation of organic nitrogen and phosphorus within the sediment. The reactive intermediates however participate in further reactions. For example volatile acids react to methane. In the model the redox reactions oxidizing these intermediates are not included, but these reduced carbon products are expressed as negative oxygen equivalents that are transported across the sediment water interface. This concept first introduced by Di Toro and Connolly enables a dynamic description of the sediment oxygen demand. A further explanation of the concept is given in the part on oxygen below. The equation describing organic carbon expressed as BOD_5 is given by:

$$\frac{dBOD_B}{dt} = \frac{a_{oc} K_{daB}\theta_{daB}^{(T-20)} A_B - \frac{5}{4}\frac{32}{14} K_{denitB}\theta_{denitB}^{(T-20)} NO3_B}{X_{conv}}$$

$$-K_{bodB}\theta_{bodB}^{(T-20)} BOD_B \tag{B-47}$$

- **Oxygen**

Dissolved oxygen in the water column is described by:

$$\frac{dO2_W}{dt} = K_{re}\theta_{re}^{(T-20)}(C_s - O2_W) - K_{BOD}\theta_{BOD}^{(T-20)} \frac{O2_W}{(O2_W + K_{bodo})} \frac{BOD_W}{X_{conv}}$$

$$-\frac{64}{14} K_{nit}\theta_{nit}^{(T-20)} \frac{O2_W}{(O2_W K_{NO})} NH4_W - \frac{32}{12} \sum_{i=1}^{3} \left[K_{resi}\theta_{resi}^{(T-20)} A_{Wi}\right]$$

$$\sum_{i=1}^{3} \left[\mu_{max\,i} F_{Ti} F_{Ni} F_{Li} A_{Wi}\right] \left[\frac{32}{12} + \frac{48}{12} a_{nc} (1 - P_{nh4}) NO3_W \right] \tag{B-48}$$

Additional to the oxidation of carbon BOD algal respiration and nitrification are included as oxygen consuming processes.

Reaeration is described using a empirical equation for the mass transfer coefficient. This coefficient is related to the flow velocity and water depth using:

$$k_{mas} = 3.94 u^{0.5} z^{-1.5} \tag{B-49}$$

or if $k_{mas} < k_{r\,min}$

$$k_{mas} = k_{r\,min} \tag{B-50}$$

The dimension of the velocity is m/s and the resulting k_{mas} is in m/day. At low stream velocity the use of eq. B-49 can result into extremely low values for the mass transfer coefficient. The user can define a minimum value for k_{mas}, which is used as a lower bound for the mass tranfer coefficient. The reaeration constant k_{re} is given by:

$$k_{re} = \frac{k_{mac}}{Z} \qquad \text{(B-51)}$$

Production of oxygen results from primary production. In case nitrate is used as a source for nitrogen an additional oxygen production takes place, because of the reduction of nitrate during the assimilation process.

The following equation is used to describe the sediment 'oxygen concentration':

$$\frac{dO2_B}{dt} = -K_{bodB}\theta_{bodB}^{(T-20)}\frac{BOD_B}{X_{com}} \qquad \text{(B-52)}$$

As stated above in the part on BOD, the organic carbon and the settled algae are mineralised anaerobically and expressed as BOD. Both reactions are considered to be sinks for oxygen and quickly drive the oxygen concentration within the sediment top layer negative. This negative oxygen concentration indicates that the redox state in the sediment is rather reduced than oxidized. The calculated negative concentration is considered to be oxygen equivalence of the reduced intermediate products produced in the mineralisation reaction mechanism. It is assumed that the reduced carbon intermediates (expressed as oxygen equivalents) are transported across the sediment interface and are oxidized to CO_2 en H_2O in the overlying water column. The sediment oxygen demand is in fact calculated as the transport of oxygen and oxygen equivalents across the sediment water interface and is controlled by the decomposition of organic carbon in the sediment and the overlying water dissolved oxygen concentration. The SOD in this concept is described by:

$$SOD = \frac{E_{diff}}{HB}(O2_W - O2_B) \qquad \text{(B-53)}$$

B.4. Parameters

Table B-1 presents a list of all parameters used in EUTROF2. In this table also the default values used are given.

Symbol	Description	Dimension	Default
$a_{chl,i}$	Chlorophyll to carbon ratio species i	ug Chl -a/mg C	30.000
a_n	Nitrogen to carbon ratio	mg N/mg C	0.25
a_o	Oxygen to carbon ratio	mg O_2/m g C	2.670
a_p	Phosphorus to carbon ratio	mg P/mg C	0.025
BOD_{LB}	BOD concentration lower sediment layer	mg O_2/l	3500.0
ε_0	Background extinction	1/m	1.0
ε_{chl}	Specific extinction chlorophyll	ug Chl -1/l.m	0.016
E_{dif}	Diffusive exchange rate constant	m^2/d	0.0002
ε_{SS}	Specific extinction suspended solids	mg SS/l. m	0.05
f_{dBODB}	Fraction dissolved BOD sediment	-	0.03
f_{dBODW}	Fraction dissolved BOD water column	-	0.90
f_{dNOB}	Fraction dissolved organic nitrogen sediment	-	0.10
f_{dNOW}	Fraction dissolved organic nitrogen water column	-	0.10
f_{dPOB}	Fraction dissolved organic phosphorus sediment	-	0.10
f_{dPOW}	Fraction dissolved organic phosphorus water column	-	0.10
f_{ralgn}	Fraction algal nitrogen released as organic nitrogen	-	0.50
f_{ralgp}	Fraction algal phosphorus released as organic phosphorus	-	0.50
HB	Depth of the sediment top layer	m	0.10
$I_{s,i}$	Optimal light intensity species i	W/m²	40.0
K_{bod}	*Oxidation rate constant BOD water column*	1/d	0.10
K_{bodB}	Anaerobic decomposition rate constant BOD sediment	1/d	0.005
K_{bods}	Oxygen half saturation constant BOD decay	mg O_2/l	2.0
K_{dB}	Anaerobic decay rate constant algae sediment	1/d	0.010
K_{den}	Denitrification rate constant water column	1/d	0.10
K_{denB}	Denitrification rate constant sediment	1/d	0.10
$K_{die,i}$	Die-off rate constant species i	1/d	0.10

K_{dno}	Oxygen half saturation constant denitrification	mg O_2/l	0.50
K_{min}	Decomposition rate constant organic matter water column	1/d	0.10
K_{minB}	Anaerobic decomposition rate constant sediment	1/d	0.001
K_{mn}	Ammonia preference constant	mg N/l	0.025
$k_{n,i}$	Monod constant nitrogen algal growth species i	mg N/l	0.025
K_{nit}	Nitrification rate constant	1/d	0.10
K_{no}	Oxygen half saturation constant nitrification	mg O_2/l	2.0
$k_{p,i}$	Monod constant phosphorus algal growth species i	mg P/l	0.005
K_{pipB}	Partition coefficient inorganic phosphorus sediment	l/mg SS	0.00250
K_{pipW}	Partition coefficient inorganic phosphorus water column	l/mg SS	0.05000
$k_{res,i}$	Respiration rate constant species i	1/d	0.05000
k_{rmin}	*Minimum oxygen transfer coefficient*	m/d	0.40000
$NH4_{LB}$	Ammonia concentration lower sediment layer	mg N/l	1.600
$NO3_{LB}$	Nitrate concentration lower sediment layer	mg N/l	0.000
$O2_{LB}$	Oxygen (equivalents)concentration lower sediment	mg O_2/l	0.000
POR	Sediment porosity	-	0.8
ρ	Density suspended solids	kg/m^3	1320
θ_{bod}	Temperature coefficient oxidation BOD	-	1.04
θ_{bodB}	Temperature coefficient decomposition BOD sediment	-	1.08
$T_{cs,i}$	Critical temperature species i	°C	35.0
θ_{dab}	Temperature coefficient anaerobic decomposition sediment	-	1.080
θ_{den}	Temperature coefficient denitrification water column	-	1.040
θ_{denb}	Temperature coefficient denitrification sediment	-	1.040
TIP_{LB}	Total inorganic phosphorus lower sediment layer	mg P/l	1.900
θ_{min}	Temperature coefficient mineralisation water column	-	1.040
θ_{minB}	Temperature coefficient mineralisation sediment	-	1.080
θ_{nit}	Temperature coefficient nitrification	-	1.080
TON_{LB}	Total organic nitrogen lower sediment layer	mg N/l	15.000
TOP_{LB}	Total organic phosphorus lower sediment layer	mg P/l	5.000
$T_{os,i}$	Optimal temperature species i	°C	20.0
$\theta_{r,i}$	Temperature coefficient respiration species i	-	1.040
θ_{rea}	Temperature coefficient reaeration	-	1.024
$\mu_{max,i}$	Maximum growth rate species i	1/d	1.200
$v_{sa,i}$	Settling velocity species i	m/d	0.00500
v_{SS}	Settling velocity suspended solids	m/d	0.000

Table B-1 Parameters used in EUTROF2

B.5. External variables

Table B-2 presents the external variables in the model. For some of the variables a typical value is provided. For the daily averaged light intensity, day length and temperature a time series of one year is available on diskette in the file RIEUT2.EXT. Light intensity and water temperature are measured at moderate latitude.

Symbol	*Description*	*Dimension*	*Default*
F_{res}	Resuspension flux	g/m^2, d	5.00
T	Temperature	°C	20.0
I_a	Average light intensity	W/m^2	100.0
L	Day length	hour	12.0

Table B-2 External variables used in EUTROF2

B.6. Flow variables

Symbol	Description	Dimension	Default
z	Water depth	m	1.00
As	Cross sectional area	m^2	20.0
Q	Flow	m^3/s	1.00

Table B-3 Flow variables used in EUTROF2

The velocity is calculated from the flow and the cross sectional area, which are defined as flow variables. This means that they are read directly from the hydrodynamic part of DUFLOW.

Initial conditions of some sediment variables

Table B-4 presents some typical values for the concentration is the sediment. These values can be very site specific and the model is rather sensitive to the initial sediment concentrations. If no data are available table B-4 provides some guide lines, which can be used as an initial guess.

Symbol	Description		Dimension	Range
NH_4I	*Interstitial ammonia concentration*		mg N/l	0.2-5.0
$NO3_I$	Interstitial nitrate concentration		mg N/l	0.0-0.1
DIP_B	Interstitial inorganic phosphorus		mg P/l	0.0-0.1
PIP_B	Particulate inorganic phosphorus		mg P/g SS	0.0-3.0
TON_B	Total organic nitrogen	0.5-5 % of the organic matter		
TOP_B	Total organic phosphorus	0.2-1 % of the organic matter		
$PBOD_B$	Particulate BOD	1.4 * organic matter content		
		organic matter content 0-50 % of the dry weight		
$DBOD_B$	Dissolved BOD interstitial water		mg O_2/l	100.0

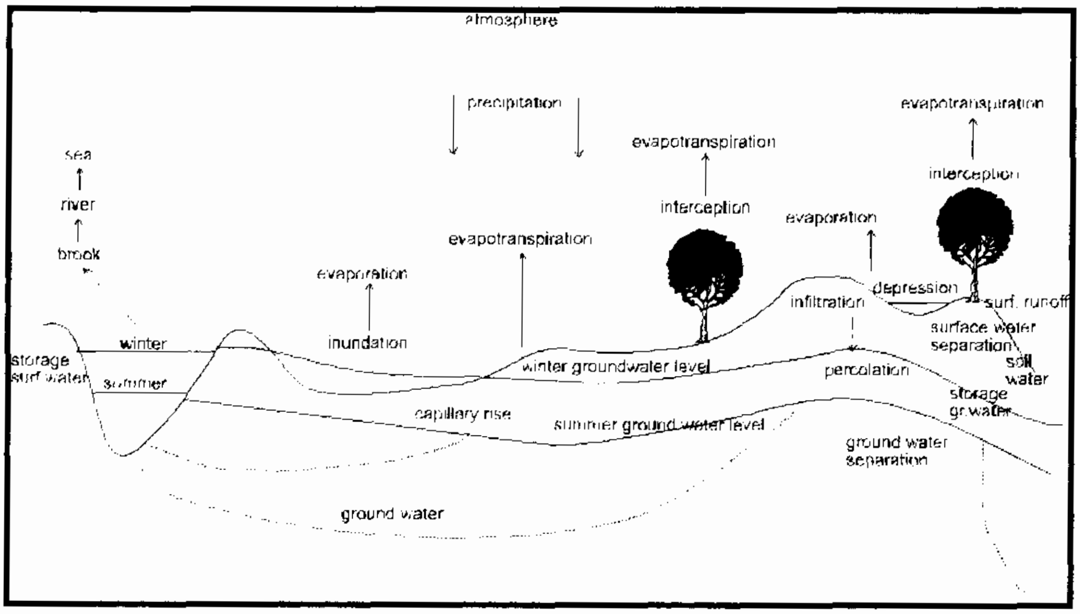
Table B-4 Some typical sediment characteristics

RAM - Precipitation Runoff Module

Reference Manual

VERSION 3.0 April 3rd 1998

Stowa / EDS



Contents

1. Introduction

1.1 Purpose

Water authorities require a dynamic management of their extensive water systems and related infrastructure to provide water for industry, agriculture, domestic supply, reduction of damage due to excess of water, water quality control, etc. In hydraulic engineering a proper design and operation of river based structures and improvement works also requires consideration of the overall water system . The use of surface water models suiting a wide range of users and their applications has become a prerequisite for optimal design and management.

One of the restrictions of most of the surface water models is the absence of an accurate description of the precipitation runoff process. In order to improve the applicability of the surface water models, STOWA has initiated the development of a precipitation runoff module (RAM).

An adequate description of the precipitation runoff processes is necessary for the prediction of runoff peaks and the prediction of the water quality in the surface water.

RAM is suitable for operational use.

1.2 About this manual

This manual is divided in the sections: Theory, General Setup and Formula's. In chapter 2 (Theory) an explanation on the hydrological cycle, the nitrogen cycle and the Phosphor cycle is given. In chapter 3 (General Setup) a general description of the model is given, while in chapter 4 (Formula's) an extensive description of the governing equations is given.

More information about the use of RAM is described in the User's Guide of the Duflow Modelling Studio DMS).

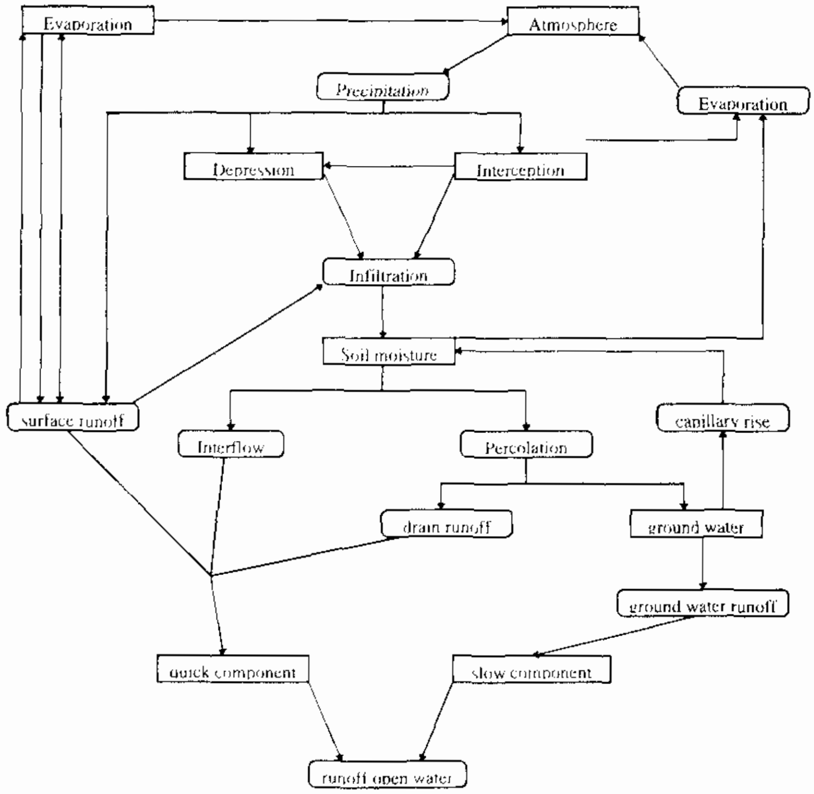


figure 2: Hydrologic cycle flow chart

In the flow chart, the ground water flows (the items seepage and downward seepage) have been left out, in order to keep the chart surveyable. Also the meltwater drainage (and storage in the form of snow) has been left out of consideration. This process is not included in the precipitation runoff module. Furthermore, artificial supply (inlet) or extraction of water have been left out of consideration.

The precipitation runoff processes are described in the following sections. In this description paved and unpaved surfaces are distinguished between.

2.2.1 Paved surface

Within paved surface a further distinction may be made in:

- Paved surface in a rural area;
- Urban area;
- Greenhouse area;

The precipitation on paved surface in a rural area is discharged immediately by means of the surface (ditches), or it is discharged by means of the ground water due to infiltration outside the paved area.

Precipitation in urban areas will partly fall on paved surface (roads, buildings) and partly on unpaved areas (parks, gardens). The precipitation on the paved surface (ground precipitation) will be drained through the sewer system. Part of this precipitation will temporarily be stored on the street surface. The precipitation on unpaved surface will be drained through the soil or the drainage system.

The way in which precipitation is discharged depends on the type of sewer system. In case of a combined sewer system, the precipitation is discharged in principle through sewage treatment plants. In case of extreme precipitation, part of the precipitation will be discharged into the surface water by means of overflow.

In case of a separated sewer system, the precipitation on paved surface will be discharged into open waters immediately. Part of the precipitation will be stored temporarily in the sewer system and in case of extreme precipitation on the paved surface. In case of an improved separated sewer system, the water is discharged to sewage treatment plants when little precipitation occurs (highly polluted water). In case of heavier precipitation, the water will be discharged directly into the surface water (this water is considerably less polluted).

The precipitation on greenhouses is discharged directly or through a water storage reservoir to surface water.

2.2.2 Unpaved surface

Within the discharge process of unpaved surface, three processes are distinguished (see figure 3):

1. Infiltration into the soil moisture (unsaturated zone)
2. Percolation into the ground water (saturated zone)
3. Ground water discharge into the drainage system

2.2.2.1 Infiltration into the soil moisture (unsaturated zone)

Precipitation on unpaved surfaces is caught by the vegetation (interception) and the soil. The amount of precipitation that is caught by the vegetation is difficult to determine, as is the amount of water that reaches the ground by flowing along the trunks of trees and through foliage. This interception causes slowing down (and also extra evaporation) of the runoff process, but has hardly any effect on the effective precipitation (Singh, 1989). In general, losses as a result of interception are small, except in woodlands.

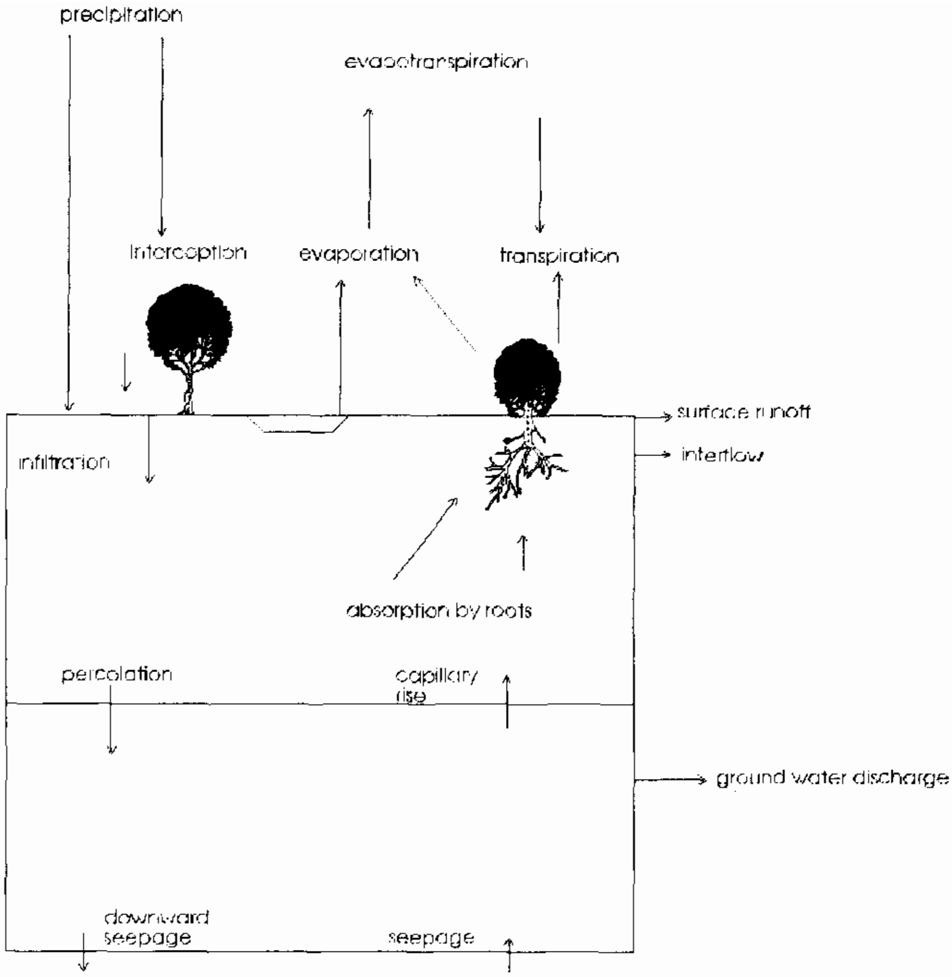


figure 3: Hydrologic processes unpaved surface

Precipitation that reaches the surface, will infiltrate and will be stored in the soil moisture zone. The amount of precipitation, which is stored in the soil, depends on the precipitation intensity and amount, as well as the infiltration capacity. The infiltration capacity describes the amount of water, which may infiltrate into the ground within a time unit. This depends on the nature and the state of the ground (water content, cultivation, presence of vegetation). If the precipitation intensity surpasses the infiltration capacity, the water stays behind on the surface level. A water film is formed on the surface, which fills the hollows (surface depressions). In case of prolonged precipitation, this precipitation will partly evaporate and partly flow off through trenches in the depressions (surface runoff). Surface runoff is characterized by short but heavy runoff/discharge peaks and represents a quick component of the runoff process.

The storage in surface depressions depends to a large extent on the roughness of the terrain. In The Netherlands, the infiltration capacity is often high and the precipitation intensity low, so that discharge of the precipitation over the surface level plays a subordinate part. In case of thunderstorms temporary storage on the surface level may, indeed, arise locally.

2.2.2.2 Percolation into the ground water (saturated zone)

In a unpaved area, the precipitation will infiltrate into the topmost soil layer. This layer, the unsaturated zone, contains both water and air and is especially important to the vegetation. Moisture in this layer may evaporate (evaporation) directly or indirectly, after absorption of moisture by vegetation (transpiration). Transpiration is the evaporation through the stomas of plants. This evaporation includes exclusively soil moisture, in quantities that are required for an optimum growth of the plant. If the amount of soil moisture is insufficient for this, this becomes the amount the plant is able to abstract. The total of evaporation and transpiration is evapotranspiration.

If the soil moisture is replenished to field capacity, the precipitation surplus will percolate into the ground water (percolation). By precluding shallow and poorly pervious layers (loamy soil, or intensive building) above the ground water surface, the infiltrated water may be drained over these layers (interflow). On low grounds part of the percolated water will be caught by drains and discharged to the drainage system.

In case of soil moisture shortage for vegetation (a soil water content below the field capacity), the soil moisture is replenished by capillary rise from the saturated zone. A condition in this case is that the ground water level is not too deep. In this way, part of the ground water becomes available again for transpiration or evaporation (Van Dam, 1985; Cultuurtechnisch Vademecum, 1988; Warmerdam, 1994).

2.2.2.3 Ground water discharge into the drainage system

Characteristic for ground water discharge is a quelled runoff peak by means of horizontal and radial resistances in the ground. In case of deep ditches (complete ditches) the horizontal resistances dominate. Radial resistances dominate in case of incomplete ditches and drains. Due to relatively large resistances in the soil, extensive slowing down occurs (Van Dam, 1985).

Quick and slow ground water discharge processes
The runoff of precipitation may consist of a slow and a quick component (see figure 4 and 5). The part of the precipitation that is drained quickly, is the quick component. It may consist of the runoff of precipitation into open water, surface runoff, interflow and runoff originating from drainpipes.

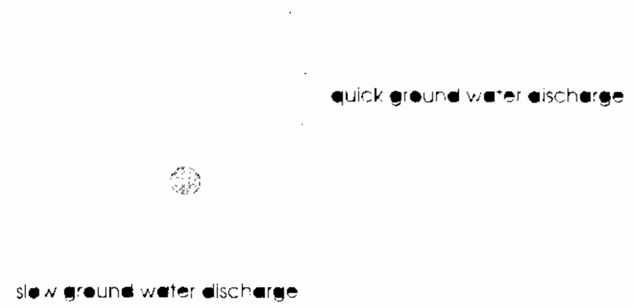


figure 4: Quick and slow components of ground water discharge

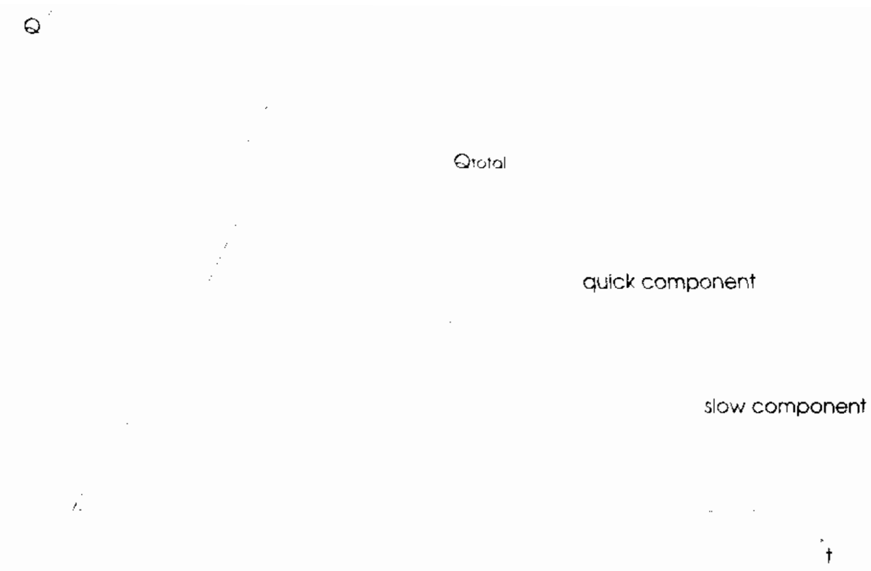


figure 5: Drainage course of quick and slow ground water discharge

The remaining effective precipitation is discharged quelled and slowed down to a relatively large extent, as a result of storage in the unsaturated and saturated zones (the slow component). The size of the unsaturated and saturated zones determines the degree of quelling and slowing down. A deep ground water level results in a large storage in the unsaturated zones. A large distance between the drainage ditches results in a large storage in the saturated zone. Also large, active pore volumes and a small horizontal transporting power result in a large storage in the saturated zone. The larger the storage and slowing down in the unsaturated and saturated zones, the more the discharge is slowed down and the discharge peak is quelled (Warmerdam, 1994).

Specific characteristics of runoff processes in The Netherlands

The precipitation runoff process in The Netherlands is generally characterized by low precipitation intensities and high infiltration capacities of the soil, in combination with slight slopes of the ground surface. This combination of factors results in runoff of the precipitation through the ground water for the greater part. Surface runoff occurs in a lesser degree.

In the Dutch situation, an intensive drainage system generally exists. The presence of open water creates extra storage capacity, which results in extra quelling and slowing down of the discharge course. The degree of quelling and slowing down depends on the pattern, the surface, the slope and the maintenance of water courses. In polder areas with a relatively high ground water level, the size of the active drainage system does not vary in accordance with the height of the ground water level. The thickness of the unsaturated zone is slight and the horizontal measurements of the ground water reservoir are constant, so that it may be expected that the total reservoir effect will be subject to only minor variations. In sloping areas increased fluctuations may, indeed, occur. This is comparable to a drainage characteristic (q-h relation). In polder areas a more or less linear relation exists, whereas in sloping areas a bended course occurs. The bends are used by increases in the active drainage system when the ground water level rises.

Generally speaking, the discharge course in an area is determined by a number of soil and terrain properties such as the size and the slope of the area, soil types, thickness and permeability of the aquifer, the storage capacity, land use and the nature and condition of the drainage system (Warmerdam, 1994).

2.2.3 Water balance

A general insight into the hydrologic cycle of a catchment area is obtained by setting up a water balance. A water balance for a catchment area has the following form:

Incoming terms = Outflowing terms + Change in storage in the area

When the time interval for which the water balance is set up amounts up to several years, the change in the storage of water may be neglected. Shorter time intervals are, however, required to determine the runoff, because the total change in the storage of water plays an important part in the relation between precipitation and discharge (see section 2.2.2).

The water balance for a catchment area is set up on the basis of figures 1 and 2. The incoming terms are the precipitation and the water inlets, the outgoing terms are the evapotranspiration and the water outlets. The total storage in a catchment area is built up by surface storage, open water storage and storage in the unsaturated zone and in the saturated zone.

The water balance worked out for a time interval is reflected below. In the left term the quantity of incoming terms are reflected; in the right term the outgoing terms and the change in the storage of water.

$$P + Q_i + K = Q_u + E + W + \Delta S$$

In which

P : precipitation in mm

Q_i : incoming flows in mm (originating from adjoining catchment areas)

Q_u : outgoing flows in mm

K : seepage in mm

E : evapotranspiration in mm

W : downward seepage in mm

Δ S : change in storage in the catchment basin for the reflected time interval in mm

The above mentioned water balance is set up for a catchment area. In paragraph 2.2.2 a distinction is made between storage in the unsaturated zone and storage in the saturated zone. The water balance may be split up into unsaturated and saturated zones to determine both storage terms. This is reflected in figure 6.

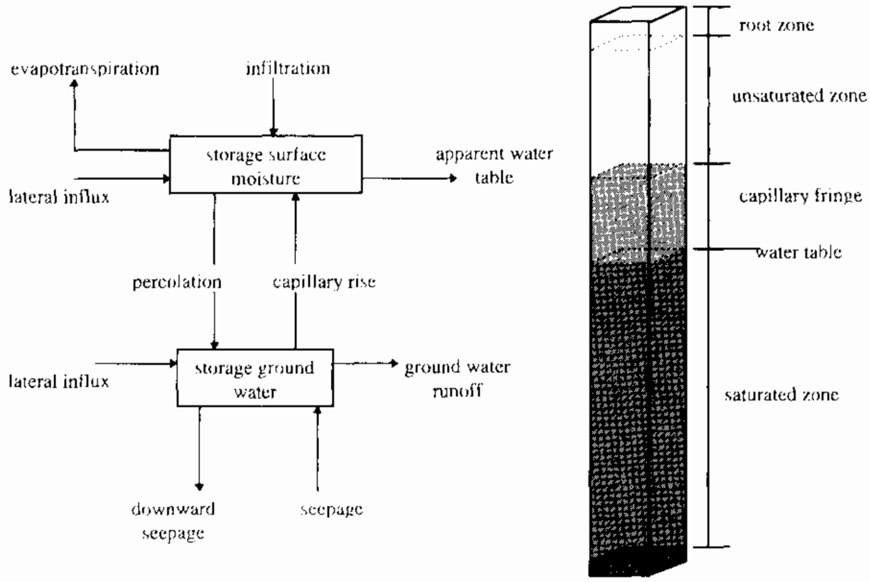


figure 6: Schematic overview terms water balance

2.2.3.1 Water balance unsaturated zone

The incoming terms of the unsaturated zone consist of infiltration, capillary rise from the saturated zone and lateral inflow. The outgoing terms are evapotranspiration, interflow and percolation to the saturated zone. The storage term is formed by storage in the unsaturated zone (soil moisture). The water balance set up for a selected time interval is:

$$Q_{\inf} + Q_{capillary} + Q_{li} = Q_{percolation} + E + Q_{interflow} + \Delta S_{unsaturated}$$

In which

Q_{inf}	: infiltration in mm
$Q_{capillary}$	: capillary rise in mm
Q_{li}	: lateral inflow soil moisture in mm
$Q_{percolation}$	: percolation in mm
$Q_{interflow}$	: interflow in mm
$\Delta S_{unsaturated}$	: storage change in unsaturated zone for the reflected time interval in mm

2.2.3.2 Water balance saturated zone

The ingoing terms in the saturated zone consist of percolation from the unsaturated zone and lateral inflow. The outgoing terms consist of capillary rise to the unsaturated zone and seepage/downward seepage. The storage term is formed by the storage change in the ground water.

The water balance set up for a selected time interval is:

$$Q_{percolation} + Q_{li} = Q_{capillary} + K + W + \Delta S_{saturated}$$

In which:

$\Delta S_{saturated}$	: storage change in saturated zone for the reflected time interval in mm

2.2.3.3 Role of the water balance in description of precipitation runoff processes

Some terms of the water balance are input in precipitation runoff models (precipitation, water inlets, water outlets), other terms are calculated (evapotranspiration and ground water discharge).

The water balance is an important tool for calibration of precipitation runoff models. A precipitation runoff model is only capable to give a correct description of the precipitation runoff processes, if the water balance is described correctly. The calibration occurs by means of comparison of the effective precipitation with the summated effective discharge. Just one single term in the water balance is calibrated, rather than fitting on the total water balance. The water balance itself is used to verify the input values for the precipitation, water inlets and water outlets. In case of an inconsistent water balance, the input values will be reconsidered and corrected eventually.

2.3 Water Quality

In the precipitation runoff module the water quality part is limited for the time being to the description of the nitrogen and phosphor balance. Hoeks et al., 1990 was used for the description of the nitrogen and phosphor balances. In figure 7 the N- and P-balances are reflected schematically. A division was made into the supply, conversion processes in the soil and the drainage.

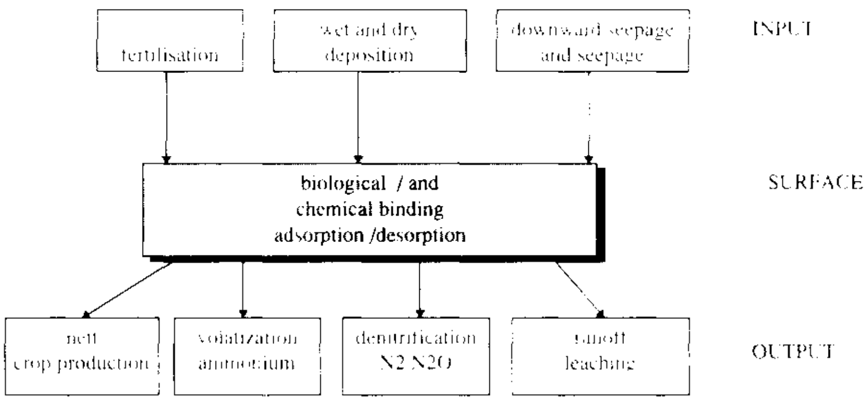


figure 7: N- and P-balances of a ground water system (Hoeks et al., 1990).

2.3.1 Supply

The supply consists of the items fertilization, deposition and seepage/downward seepage. The N- and P-load of the soil in The Netherlands in 1985 is listed in table 1 to illustrate the size of the various items.

Fertilization
From the overview above, it appears that fertilization, especially the degree and the way of fertilizing, plays an important part in the nitrogen and phosphor balances. The fertilization is bound by rules as recorded in the AMvB "Gebruik Dierlijke meststoffen" (Use of manure) of 1987. Fertilization mainly occurs during the growth season. The nitrogen in manure is deposited for about 70% onto grassland, 25% onto green maize plots and 5% onto other farmland. Nitrogen in artificial fertilizer is deposited for about 80% onto grassland and 20% onto other farmland (Kroes et al., 1990).

Table 1: N- and P-load of the ground in The Netherlands in 1985 (Kroes et al., 1990)

	N-load (tons N/year)	P-load (tons P/year)
Total	1.069.000 (100%)	140.508 (100%)
Fertilization: • Manure • Fertilizer	(87%) (44%) (43%)	(99%) (74%) (25%)
Deposition: • Wet deposition • Dry deposition	(13%) (5%) (8%)	(<1%)
Seepage/downward seepage	<1%	<1%

Deposition
The wet deposition consists of nitrogen supply through the precipitation. The "Landelijk Meetnet Regenkwaliteit" (National Measuring Network Rain Quality) (KNMI/RIVM) may be used to obtain data about the concentrations. Dry deposition consists of dust particles falling from the air onto the soil. The dry deposition is area-dependent.

Seepage/downward seepage
The contribution of seepage and downward seepage to the total P- and N-load in The Netherlands is very slight on average. Locally, this may, however, be an important resource, especially in North and South Holland.

2.3.2 Reaction processes in the soil

The reaction processes in the soil for nitrogen and phosphor are fundamentally different and are, therefore, treated separately.

Nitrogen
In the soil, nitrogen may exist in various forms and may be mutually converted into each other. Figure 8 shows a schematic overview of this.

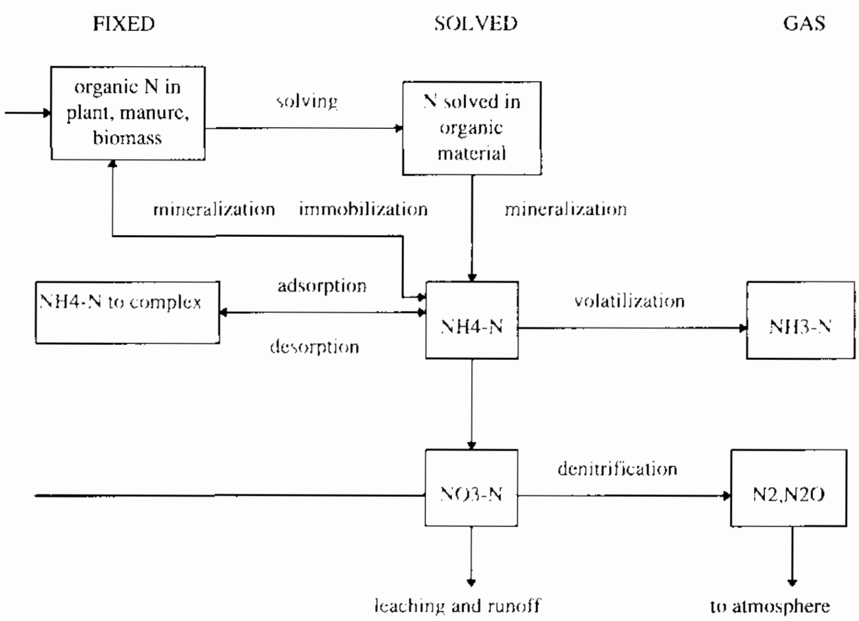


figure 8: Schematic overview of the nitrogen balance in the ground

INTERMEZZO I: Illustration of N-balance in the soil

The presence of nitrogen in the soil may be subdivided into:

- Fixed nitrogen: as part of usually organic compounds, as part of plants, humus/biomass, or adsorbed to soil complexes.
- Solved nitrogen: especially ammonium and nitrate, also called mineral nitrogen. These are present in the soil, because of:
  - Supply of solvable nitrogen (see section 2.3.1)
  - Mineralization of N into a fixed substance, during which ammonium is formed.
    In the soil, ammonium is converted into nitrate by so-called nitrificating bacteria:

    $NH_1 + 2O_2 \rightarrow NO_3 + 2H^4 + H_2O$ (by Nitrobacter and Nitrosomas spp.)

These bacteria have the following characteristics:

- They are aerobic; this means that they use oxygen in their metabolisms and, therefore are able to exist only under oxygen-rich conditions;
- They are autotrophic and use CO_2 as carbon source, instead of organic nitrogen compounds. This means that the nitrification is independent of the organic content in the soil. Nitrate is converted into N_2 by denitrifying bacteria in the soil.

Important characteristics of these bacteria are:

- Denitrification mainly occurs in an anoxic environment, this means in the absence of oxygen and in the presence of nitrate. Under these circumstances, nitrate instead of oxygen is used as donor of electrons in the metabolism of the bacterium;
- The bacteria are heterotrophic and require a carbon source, mainly short carbon chains. The fraction of organic matter in the soil and the mineralization degree of this, therefore, influences the denitrification.

Nitrification of the soil especially occurs in the oxygen-rich toplayer and denitrification occurs in the oxygen-poor bottomlayer (in anoxic layers in the saturated zone). The ground water level determines the availability of oxygen in the soil to a large extent.

Above the ground water table, more oxygen is present than under it. From modeling the catchment areas Beerse and Reusel, it appears that the nitrate concentration may rise to 100 mg NO_3-N/l in case of deep ground water levels, whereas the nitrate concentration is practically zero in case of high ground water levels. In addition to the ground water level, the organic content of the soil has an important influence on the nitrogen balance. High organic content lead to high conversion velocities, which causes the availability of oxygen in the ground to be exhausted quicker. In these circumstances, the denitrification will be predominant compared to the nitrification. In case of a low organic matter grade in the ground, this ratio is different.

With N-balance, microbiologic processes play an important part. Generally, microbiologic conversion processes are influenced by temperature, soil moisture content and pH. The discharge of nitrogen from the soil compartment is mainly determined by the type of soil, the ground water level and the ground use (among others: fertilizing).

Phosphor

Figure 9 shows a scheme of the phosphor balance in the soil.

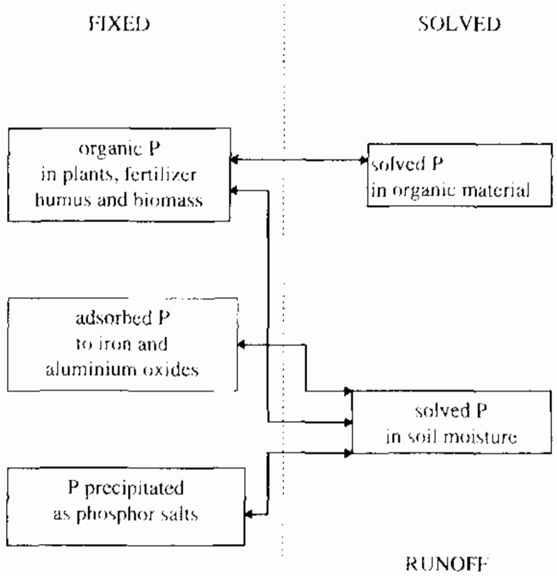


figure 9: phosphor balance in the ground

INTERMEZZO II: Illustration of P-balance in the ground

Phosphor in the soil may be subdivided into:

P in fixed substances
- P in biomass: The plants absorb phosphor for growing and incorporate it in the cell material of the plant. Also bacteria in the soil contain a fraction of phosphor;
- P adsorbed to iron and aluminium oxides. Many soil types have a significant phosphor fixation capacity, dependent on the structure and Fe and Al contents. The phosphor fixation capacity differs per type of soil. The phosphor fixation capacity for clay soil is, for example, much higher than for sandy soil;
- The phosphor absorbs/complexes Al- and Fe-oxides in the soil. If the utilization degree of the phosphor fixation capacity is higher than 25%, it is phosphor saturated ground;
- P in precipitation: phosphate forms precipitations in the form of for example iron hydroxide complexes, calcium and barium phosphate;

P in solution
- Desorption of phosphor. P partly becomes solvable again due to desorption. The concentration is determined by the adsorption/desorption equilibrium in the soil. This equilibrium may be described by a so called normalized Freundlich isotherm (Kroes et al., 1990). The equilibrium depends on the P-content in the soil moisture, the phosphor fixation capacity and specific reaction velocity coefficients.
- Decomposition of organic matter. Due to rot of plant material, the fixed phosphor partly becomes solvable again.

Conclusions conversion processes nutrients

In summary, it may be posed that microbiologic processes play a main part in the nitrogen balance in the soil, whereas these are physical/chemical processes in the phosphor balance.

Important factors in the P-balance are:

- Type of soil (phosphor fixation capacity);
- Ground use (fertilization, utilization degree phosphor fixation capacity).

Import factors in the N-balance are:

- Ground water level;
- Organic matter content;
- Ground use (fertilization).

2.3.3 Discharge

The drainage of nutrients mainly occurs through the discharge of precipitation. In addition, nutrients disappear from the soil compartment due to absorption by plants. Discharge with water is usually subdivided in runoff (through surface runoff) and leaching (via ground water discharge).

Surface runoff (runoff)
In case of high water levels, or heavy precipitation, surface runoff may occur. Together with the rain water washing off, an amount of nutrients is directly discharged into the nearby surface water. This phenomenon may be reflected schematically in such a way that the rain water ends up in an imaginative surface reservoir, in which a complete mixing occurs (Kroes et al., 1990). In case of high precipitation intensities water will flow off from this place over the ground surface. Due to the reservoir effect, the concentration course of runoff is relatively constant during a small time scale. On a larger time scale, variations in the concentration course will occur, dependent on factors such as fertilization level and absorption by crops.

Ground water discharge (leaching)
In section 2.2.2 a number of components are distinguished, which form the ground water discharge. These are interflow, drainage-discharge and slow ground water discharge. The substances flow that is drained with this component is leaching. In practice, leaching is mainly determined by drainage-discharge.

Other drainage
Part of the nitrogen and phosphor is absorbed by plants and removed from the land during harvest. The fertilization policy in The Netherlands is aimed at an equilibrium between fertilization dose and nutrient absorption. In practice, however, this is most seldom the case. In most situations, surplus manuring occurs.

Table 2: Example of N- and P-balance (kg/ha year) of the soil unto the ground water level of intensively fertilized grassland (sand soil) (Drent 1994).

	Nitrogen		**Phosphor**	
	organic	mineral	organic	mineral
Supply				
animal fertilizer	185	185	20	80
artificial fertilizer	-	400	-	-
harvest losses	125	15	10	-
deposition	-	30	-	-
mineralization	-	250	1	1
Discharge				
volatilization	-	80	-	-
gross plant absorption	-	660	-	60
mineralization	250	-	20	-
denitrification	-	100	-	-
leaching and runoff	5	40	0,5	1
Accumulation	55	0	9,5	39
In root zone (kg/ha)	10.000	100	1.000	2.500

Drainage of the soil compartment also occurs through volatilization of ammonium. The share of volatilization has decreased significantly during the past few years, due to a change in the fertilization dose, such as injecting the fertilizer into grassland and ploughing in the fertilization on the farmland within one day. Finally, nitrogen escapes from the ground in the form of N_2, which comes into being during denitrification (see section 2.3.2).

In table 2 an example of an N- and P-balance of the ground of intensively fertilized grassland unto the ground water level is reflected. It appears from this table that the total amount of nitrogen, which is circulating annually, is less than 10% of the total storage. This amounts to less than 3% for P. During discharge, the point of departure is a quick decomposition of mineral nitrogen that results in a reduction of 80-90% of the N.

3. Translation Theory into General Set-up

The design of the precipitation runoff module is in line with the models that are applied in the Dutch situation, whenever possible. In addition, the most important bottlenecks in the current use have been solved in this design. During the design process, a survey was held among water boards to investigate which bottlenecks and wishes existed. The main conclusions of this investigation are:

Linear reservoir models are applied frequently (De Zeeuw-Hellinga, Krayenhoff Van de Leur, De Jager or the Nash-cascade);

Linear reservoir models start from the effective precipitation as input. The determination of the effective precipitation lacks from these models (the part of the precipitation that is actually discharged).

Based on these conclusions, the design includes a soil moisture reservoir for the determination of the effective precipitation, linked to a linear reservoir model for the description of the discharge course. In addition, a division into types of surface is made in view of the differences in precipitation runoff processes. For example, in case of a paved surface only a quick runoff process will occur, whereas an unpaved surface includes a slow component. By distinguishing between types of surface and between subprocesses, the framework of the precipitation runoff module is defined. In view of the objectives, the emphasis of the precipitation runoff module is at the description of the runoff processes of unpaved area. Figure 10 shows the framework of the precipitation runoff module.

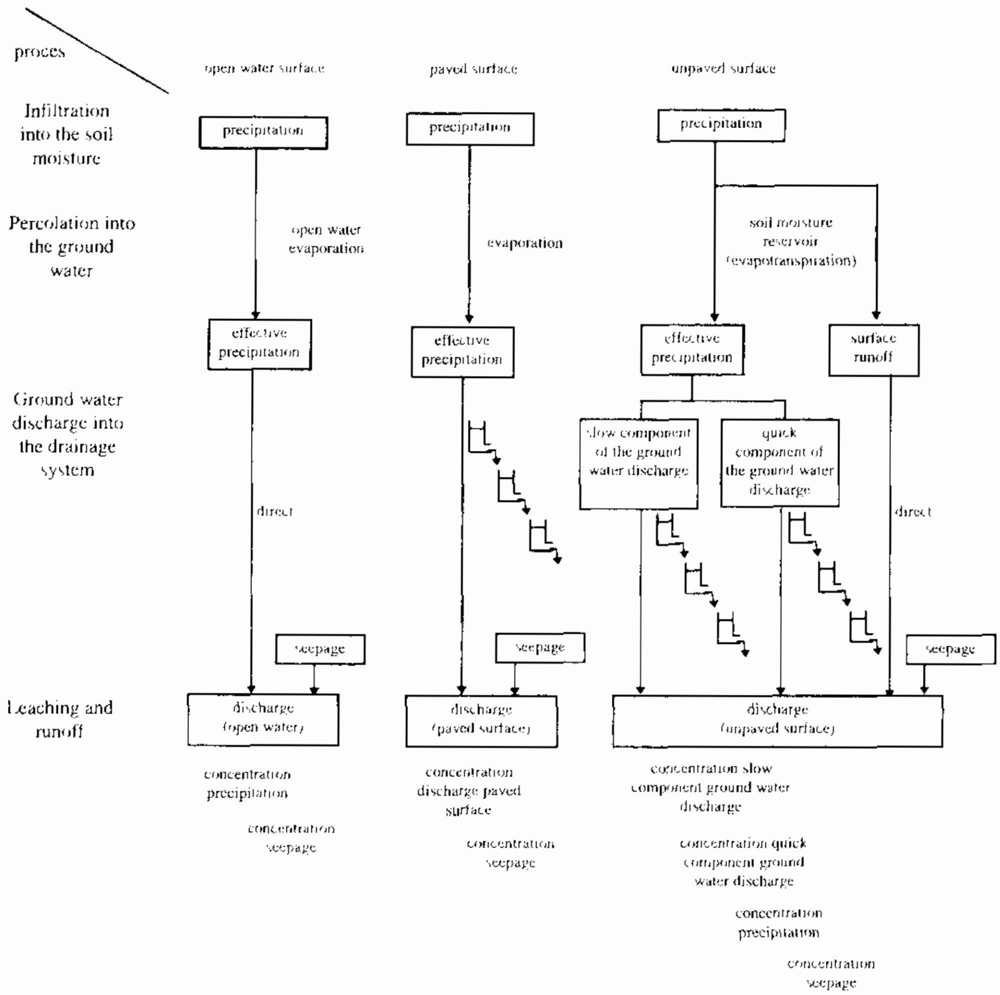


figure 10: Framework of the precipitation runoff module

This chapter deals with the translation of the theoretical system description (chapter 2) into the general set-up of the design (chapter 4). It argues the choices which were made, which processes were included or excluded, which simplifications were made etc. This is worked out further in detail for each type of surface. Finally the set-up for the water quality part is worked out. Chapter 4 describes the technical design of the precipitation runoff module.

3.1 Open water surface

In open water losses are due to evaporation only. The effective precipitation is therefore simply calculated as precipitation minus the open water evaporation.

The hydrograph is described by means of a single linear reservoir, describing the effect of delay due to storage in the open water itself.

3.2 Paved surface

The losses occurring in case of paved surfaces, consist of moistening and evaporation of the wet surface. These losses have been put equal to the open water evaporation and will be minor in general.

In the description of the hydrologic cycle paved surface has been divided into:

- Paved surface in rural area;

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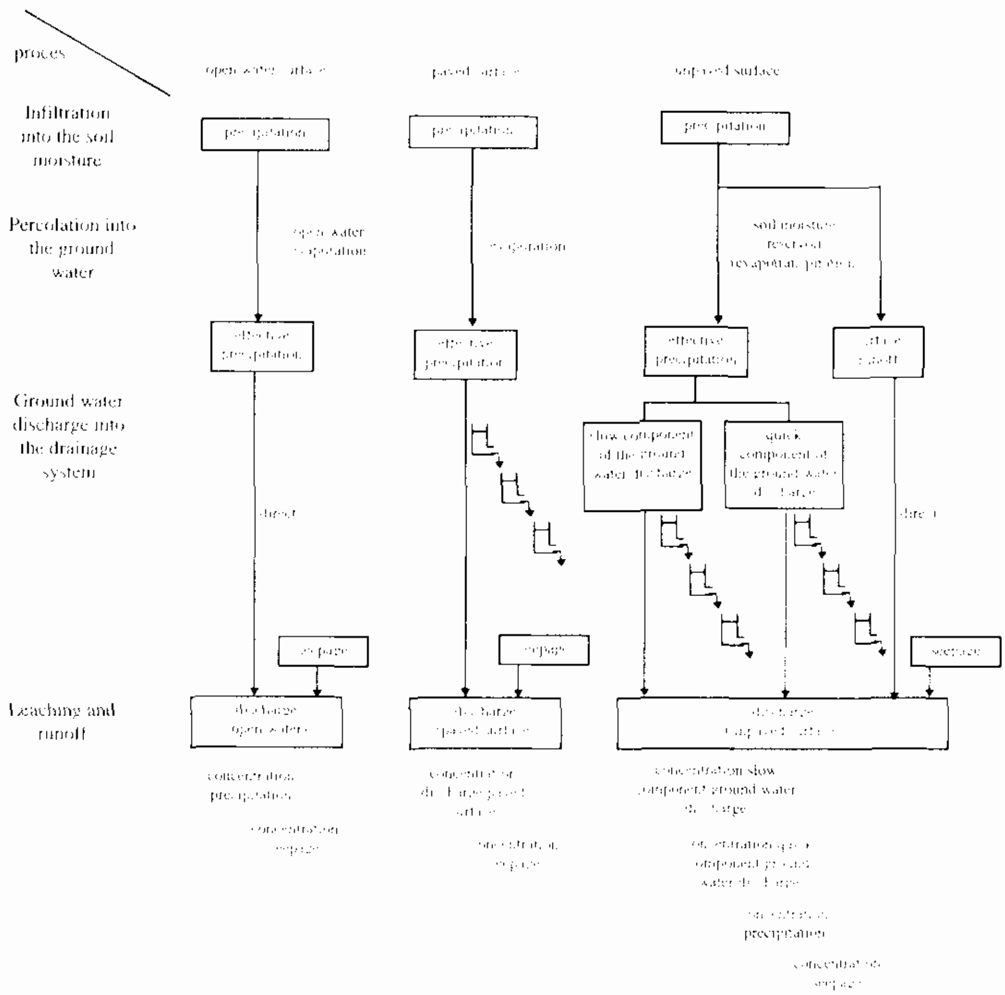

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In the description of the hydrologic cycle paved surface has been divided into:

- Paved surface in rural area;

- Urban area;
- Greenhouse area.

The discharge from paved surface is therefore divided into two subflows:

1. Paved surface discharging directly through the drainage system;
2. Surface discharging through a separated sewer system.

3.2.1 Rural area

The discharge of paved surface in rural areas may be entered directly under subflow 1 (paved surface that discharges directly through the drainage system).

3.2.2 Urban area

The discharge of urban areas occurs through the sewer system. The way of discharge is dependent on the type of sewer system. In case of a mixed sewer system, the precipitation is discharged in principle through sewage treatment plants. In case of extreme precipitation, part of the precipitation will be discharged into the surface water by means of overflow.

The effluent discharge of sewage treatment plants is measured in general. In the set-up of the precipitation runoff module this discharge is not included, but the point of departure is that it is entered directly into the flow model. This also applies to the discharge of overflows.

In case of a separated sewer system, the precipitation on paved surface will be discharged by the sewer system through the drainage system immediately. Part of the precipitation will be stored temporarily in the sewer system and on the paved surface. In general, specific models (Nationale Werkgroep Riolering en Waterkwaliteit, 1990 and Werkgroep Afvoerberekeningen [Workgroup discharge calculations], 1979) are used for the description of the discharge course. The output of these models may be used directly as input for the flow model.

In the precipitation runoff module an improved separated sewer system is treated equal to a separated sewer system. An improved sewer system can therefore be simulated identically.

The discharge from a separated sewer system is described in a sharply simplified way. The user is able to choose between:

Detailed application (calculate discharge from the sewer system by a specific model);

Simple applications (calculate discharge from the sewer system by the precipitation runoff module).

The choice between both applications will depend on the desired accuracy of the calculations and the presence of input data.

3.2.3 Greenhouse area

The discharge from greenhouse areas may be entered directly under subflow 2 (paved surface that discharges directly through the drainage system). With this, it is not possible to simulate a storage reservoir.

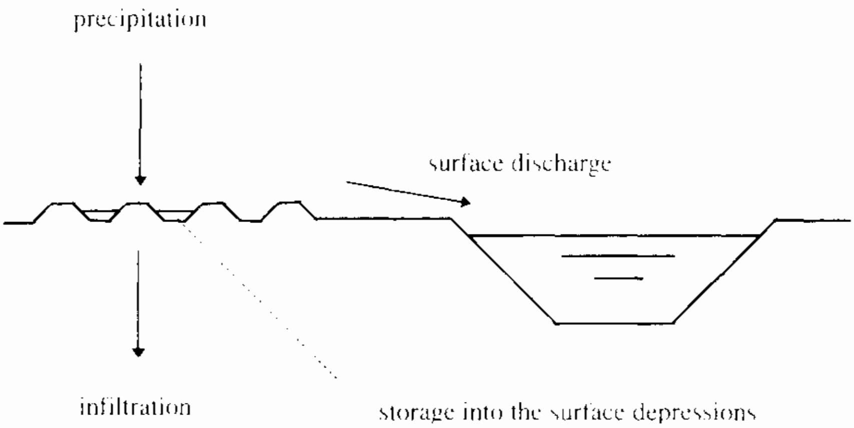
3.3 Unpaved surface

For the runoff processes of unpaved surface, three processes were distinguished in the precipitation runoff module (see section 2.2.2):

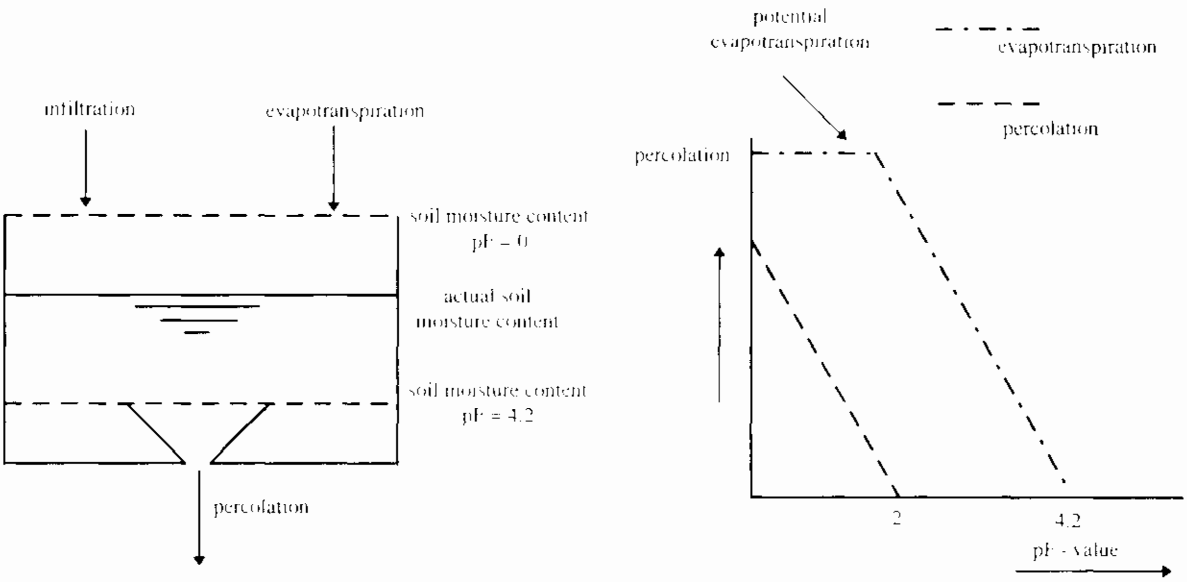
1. Infiltration into the soil moisture (unsaturated zone)
2. Percolation into the ground water (saturated zone)
3. Ground water discharge into the drainage system.

These processes are distinguished in the precipitation runoff module also. This set-up is reflected in figure 11.

process A. Infiltration into the soil moisture



process B. Percolation into the ground water



soil moisture reservoir

evapotranspiration and percolation relation process C. Ground water discharge into the drainage system

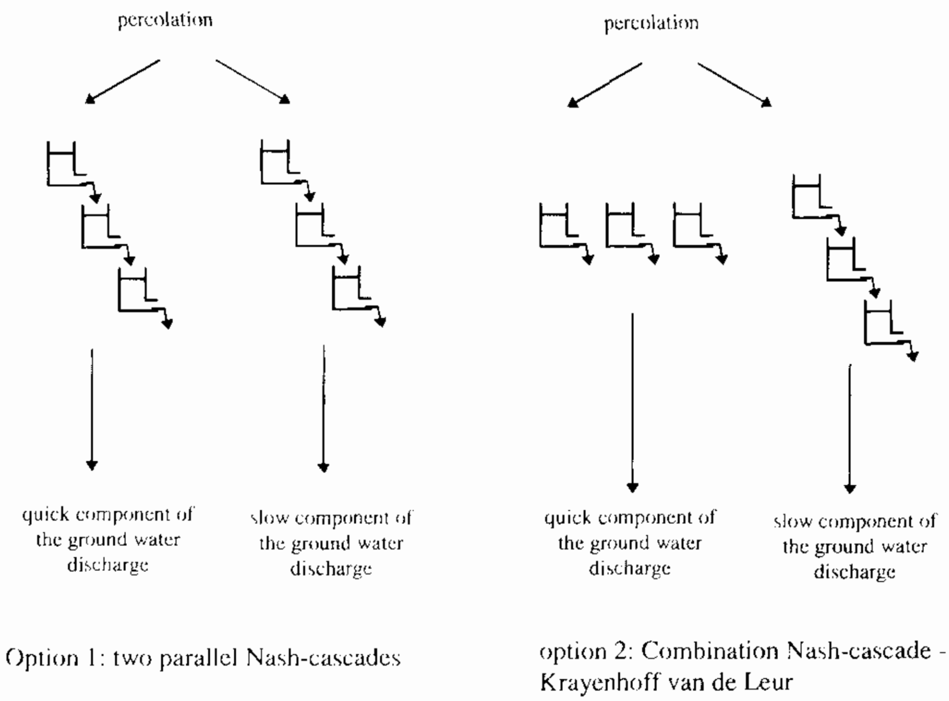


figure 11: Set-up runoff processes unpaved surface

3.3.1 Infiltration into the soil moisture (unsaturated zone)

The infiltration into the soil moisture is determined simultaneously to the processes as described in section 2.2.2. A water balance is worked out for the precipitation in surface depressions, where the precipitation is either infiltrating into the soil moisture or is discharged as surface runoff. The amount of precipitation that infiltrates is determined by the infiltration capacity of the soil, where the infiltration capacity is assumed constant in time. If the precipitation intensity surpasses the infiltration capacity, the remaining part of the precipitation will be stored on the surface level in the surface depressions. If the maximum storage in the surface depressions is surpassed, the extra precipitation will runoff over the surface as surface runoff.

3.3.2 Percolation into the ground water (saturated zone)

In the description of percolation into the ground water regarding the precipitation runoff module, a choice has been made between a physical-mathematical description of the processes and a description based on analogy of the occurring processes, without describing these exactly (conceptual models). The considerations made to arrive at the choice for the precipitation runoff model are addressed below in further detail.

The discharge of precipitation is determined by a number of input data (evapotranspiration and precipitation intensity) and by various soil and terrain properties of the catchment area (infiltration capacity, actual maximum and minimum moisture storage, the degree of drainage, presence of loamy layers, thickness of the unsaturated zone, etc.). Especially the soil and terrain properties may vary widely within a catchment area. These are not only dependent on the type of soil, but also on the ground use and the stage of growth. In addition, a number of parameters are often unknown (such as infiltration capacity). Therefore, it is not simple to translate these soil properties into area parameters.

Physical-mathematical models are based on a description of the occurring processes. Modeling these requires a vast amount of parameters to be entered. A large part of these parameters will, however, be unknown, and the translation into area values is difficult.

In order to steer clear of the above-mentioned problems, conceptual models are often used for precipitation runoff models. The models describe the 'hydrograph' rather then the real runoff processes. An example of a conceptual model is the Wageningen model. In this model the nature of the various processes is described ('soil moisture' reservoir for the storage in the unsaturated zone, convection-diffusion equation and model Krayenhoff van de Leur for the quick respective slow ground water runoff). The parameters in the model do not have a direct (measurable) physical meaning, but should be determined by calibration. In the model it has been attempted to limit the number of parameters, so that a set (as much as possible) independent parameters comes into existence.

It is important to distinguish between the various runoff processes (surface runoff, interflow, drainage and slow ground water discharge) for a correct description of the water quality. In physical-mathematical models this distinction is made, in conceptual models it is not made. It is remarked, however, that the various runoff processes cannot be measured separately, so that with regard to this aspect little significance may be attached to the results of a physical-mathematical model.

The point of departure in the development of the precipitation runoff module is a model for operational use (simple set-up with a limited number of input parameters). A physical-mathematical model requires extensive knowledge of the processes and a relatively large number of parameters need to be determined. Therefore, a conceptual model fits the point of departure of a precipitation drainage module for operational use (simple set-up) in a better way. For this reason a conceptual model was chosen for the precipitation runoff module. Hereby the point of departure is the soil moisture reservoir taken up in the Wageningen model. In addition, the adaptations proposed by the steering committee and the external experts have been included.

A water balance of the amount of moisture in the unsaturated zone is maintained in the soil moisture reservoir. The replenishment of soil moisture in the soil moisture reservoir is the calculated infiltration, the outflow is calculated as the evaporation and the percolation to the ground water (see figure 11). Both the evaporation and the percolation depend on the actual soil moisture content. The potential evapotranspiration is determined based on the reference crop evapotranspiration and a crop factor. If crops have not been supplied with water in an optimum way, the actual evapotranspiration is smaller than the potential evapotranspiration. The reduction is calculated by means of a linear relation between the evapotranspiration and the actual soil moisture content, where the actual evapotranspiration decreases form the potential evapotranspiration at field capacity towards zero at the wilting point. The percolation into the ground water also depends on the actual soil moisture content. This is described by means of a linear relation between the percolation and the actual soil moisture, where the percolation decreases form the maximal percolation at saturation towards zero at field capacity.

3.3.3 Ground water discharge into the drainage system.

Finally the effective precipitation will discharge as ground water into the drainage system. Due to the resistance of the soil for water flow, a significant slowing down effect will occur due to storage in the soil. Due to the similarity of the discharge processes with a delayed discharge due to the resistance in the soil, and a linear reservoir with a delayed discharge due to the resistance of the opening, this process is described by means of linear reservoir models. Besides the interflow and the drainage discharge, a quick and slow component were distinguished in the ground water discharge in the theoretical system description (section 2.2.2). This distinct was made because of the difference in characteristics of the processes and water quality. Both the quick and slow component of the ground water discharge can be defined as a configuration of linear reservoirs. Two options are incorporated in the precipitation runoff module:

1. Two parallel Nash-cascades;
2. Combination of Nash-cascade and Krayenhoff van de Leur.

In the first option, both the hydrograph of the quick and slow component are described by a number of linear reservoirs in series, a Nash-cascade. In the second option, the hydrograph of the quick component is described by means of a number of linear reservoirs parallel, Krayenhoff van de Leur, the slow component by means of a number of linear reservoirs in series, a Nash-cascade. Using both options, it is possible to simulate all widely applied models such as De Zeeuw-Hellinga, Krayenhoff van de Leur, Nash-cascade and De Jager. Varying the time constant of the reservoir and the number of reservoirs, the user can specify the model according to the application. For relatively quick discharge processes one reservoir with a small time constant of the reservoir will be sufficient, for a relatively slow discharge process more reservoirs with a small time constant of the reservoir will give a better description.

3.4 Total runoff

In addition to the ground water runoff a term seepage is included. This is explained further in section 4.5. The total runoff of a catchment area consists of the discharge from the three types of surface and the term seepage:

- Open water ($Q_{open\ water}$);
- Paved surface (Q_{paved});
- Unpaved surface ($Q_{unpaved}$);
- Seepage (Q_{seep})

The drainage of unpaved surface consist of the runoff of the subflows:

- Surface runoff (Q_{sur});
- Quick component ground water discharge (Q_{quick});
- Slow component ground water discharge (Q_{slow});

3.5 Water quality

The composition of the discharged precipitation depends strongly on area-specific properties such as soil properties, degree and intensity of fertilization and land use. In practice, usually no measuring data per catchment area are available. An additional complication is that various subflows may be distinguished, which differ in flow rate and quality. Measuring data for each subflow regarding flow rates and composition should be available, in order to be able to draw a final picture of the quality. Possibly, it may be tried to determine a quality-flow rate relation for the drained precipitation. However, this requires an extensive and lengthy measuring program. Only few data are found in the literature.

An alternative for an intensive measuring campaign for surface water or subflows is the use of a model, in which the quality development of the drained precipitation is simulated based on a small number of input parameters. In the technical design a subflow approach has been worked out. It was tried to indicate a quality (development) for all the subflows, based on the literature. Target values are split up for type of land use and degree of fertilization. It was not possible to find 'target values' for all the subflows using this method. It is important to understand that this is about strongly simplified target values (possibly with bandwidths) with a certain inaccuracy. The user may decide whether it is possible to calculate with these in a sufficiently reliable way, or that a supplementary measuring campaign should be carried out.

Both solutions mentioned above include disadvantages. Measuring campaigns are expensive and compared to the required space and time, usually provide a very limited picture only. Models are a (strongly) simplified reflection of the reality, so that area-specific properties or essential processes may be lacking. In the precipitation runoff module a pragmatic model has been chosen as the solution. A big advantage of this is that water managers will receive a tool to obtain a first impression of the background values, also in case measuring data are lacking for the greater part and that they will be able to continue their model studies. Based on this tool, they will be able to decide for themselves whether the required reliability is fulfilled for the objective of the question. A comparison with the quality development of the receiving surface water can be made quickly, so that serious mistakes will be noticed. Should it appear that the precipitation runoff module differentiates to little in many cases, it may then be decided to carry out measuring campaigns until further notice.

Similar to the hydrograph it is strongly recommended to calibrate the model on measured concentration.

The runoff of nutrients of paved surface, organic fixed N is a main component (NWRW, 1986). This term has not been included in this version of RAM.

3.6 Remarks

Only part of the drainage system (primary canals) are included in the flow model. Within the catchment area defined, also a drainage system is present (secondary and tertiary canals). These watercourses are indicated in the precipitation runoff module as 'open water surface'. The contribution of open water surface to the total runoff can be neglected in most situations, because it is only a small surface. But, the discharge from open water surface directly affects the water level.

As part of the schematisation, the user will define the catchment areas in the flow model. The precipitation runoff processes within a catchment area are determined by soil and terrain properties, such as slope and soil type (see chapter 2). The properties may, however, also vary strongly within the defined catchment area. The point of departure in the precipitation runoff module is that only the types of surface (open water, paved and unpaved surface) are distinguished. Within these surfaces, the catchment area is regarded as being homogeneous: the soil and terrain properties may be described as one (weighed) average value. The spatial variety within the defined catchment area is translated by the model's parameters. This implicates that the user him/herself is responsible for splitting up a catchment area, if a diversity of soil and terrain properties clearly exists.

In the model the runoff course is determined at the discharge point of a catchment area. Within a catchment area, however, also a drainage system is present. In case of large catchment areas, storage in the surface water may play a part. This is discounted in the linear reservoir.

The elements from the Wageningen model (Warmerdam, 1993) and the model BUIBAK (Hartman, 1994) are incorporated in the precipitation runoff module.

4. Formulas

4.1 General

Structure of technical design description
The technical design is worked out per type of surface. The types of surface distinguished are:

- Open water surface (section 2.3.2);
- Paved surface (section 2.3.3);
- Unpaved surface (section 2.3.4);
- Seepage (section 2.3.5).

After that, the technical design is worked out in further detail per subprocess for each type of surface. The subprocesses described in subsections are:

- Storage in unsaturated zone (determination of effective precipitation);
- Storage in saturated zone (determination of runoff course);
- Description of the water quality.

Time step
The user defines the time step in the precipitation runoff module, which remains constant during the calculation. It is recommended to use time steps similar to the time step used in input data as precipitation and evaporation, commonly given as 24 hour data.

Calculation discharge from linear reservoirs
The calculation of the runoff takes place in two steps. First the specific discharge (unit: [mm/day]) per time interval is calculated. Because the inputted precipitation intensity and reference vegetation evaporation applies to the preceding time interval, the specific discharge at point of time t is defined as the specific discharge during the time interval t-1 to t. In the second step, the specific discharge is converted to the momentanious discharge at the end of the time interval defined at point of time t (unit: [m^3/s]).

Definition precipitation and evaporation time interval
The daily observations of the KNMI are usually used for the precipitation intensity and the reference vegetation evaporation. The precipitation intensity and the reference crop evaporation are defined at time interval t from point in time t-1 to point in time t (the preceding time interval). The precipitation intensities provided by the KNMI are the intensities measured during the period from 08:00 hours on the preceding day to 08:00 hours on the day involved. The reference crop evaporation is the evaporation measured during a period from

24:00 hours on the preceding day to 24:00 hours on the day involved (KNMI, 1995).

Description Water Quality
The emphasis of the water quality is at the prediction of loads for ammonium ($NH4$), nitrate ($NO3$), and phosphor ($PO4$). The loads are determined as the products of the calculated discharges and the concentrations. The concentrations of the nutrients can be derived from the target values, as obtained from the literature. The target values are stated when found in literature, specified for land use, soil type and type of discharge, surface runoff, slow and quick component of the ground water discharge.

4.2 Open water surface

4.2.1 Determination of effective precipitation

The effective precipitation for open water is easy to determine. The losses are equal to the open water evaporation according to Penmann (GHO, 1988). The effective precipitation per time interval amounts to:

$$P_{N,open\_water,t} = P_{b,t} - f_0 E_{r,t} \qquad (1)$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	$E_{r,t}$	[mm/day]	Reference crop evaporation Makkink
Model parameters	f_0^*	[-]	Crop factor Makkink for open water
Output	$P_{N,open\_water,t}$	[mm/day]	Effective precipitation open water surface

* The crop factor for open water is equal to E_0 / E_R in which E_0 is the open water evaporation according to Penmann. The factor varies somewhat but may approximately be equated with 1.25 (Cultuurtechnisch Vademecum, 1988)

During dry periods the open water evaporation is larger than the precipitation intensity. In this case a negative effective precipitation is calculated, which equals a precipitation shortage, simulating evaporation out of surface water in the drainage system.

4.2.2 Description of the Hydrograph

The drainage of the open water surface is determined by means of one linear reservoir.

$$q_{open\_water,t} = q_{open\_water,t-1} e^{-\Delta t / k_0} + P_{N,open\_water,t} (1 - e^{-\Delta t / k_0}) \qquad (2\text{-a})$$

$$Q_{open\_water,t} = aA_{open\_water} q_{open\_water,t} \qquad (2\text{-b})$$

Input	$q^{*}_{open\_water,t-1}$	[mm/day]	Specific discharge open water surface (formula 2-a)
	$P_{N,open\_water,t}$	[mm/day]	Effective precipitation open water surface (formula 1)
	A_{open_water}	[ha]	Open water surface
Model parameters	k_0	[day]	Time constant reservoir open water surface
	Δt	[day]	Time step
	a^{**}	[-]	Conversion factor units
Output	$Q_{open\ water,t}$	[m³/s]	Discharge open water surface

* For $q_{open\_water,t-1}$ at point of time t = 0 a value of 0 is taken

** The conversion factor is equal to 10/(24 * 3600)

Target values time constant
In practice, hardly any slowing down of the discharge through open water will occur. In this case a value of 0 may be taken as time constant. In relatively large catchment areas slowing down may, however, play a part. In this case a target value of 0.0014 à 0.002 days may be taken as time constant, in accordance with a time constant of paved surface (Cultuurtechnisch Vademecum, 1988).

4.2.3 Description water quality

Nitrogen
The nitrogen in the precipitation on open water forms a direct emission source to the water (the time interval between the precipitation supply and the precipitation drainage to the water is zero). This means that no processes occur that are able to influence the N-content in the meantime. The nitrate and ammonium loads through this flow to the canals may, therefore, be described in accordance with the zero order relation:

$$S_{NH4-N,open\_water,t} = Q_{open\_water,t} \times C_{NH4-N,precipitation,t} \quad (3\text{-a})$$

$$S_{NO3-N,open\_water,t} = Q_{open\_water,t} \times C_{NO3-N,precipitation,t} \quad (3\text{-b})$$

Input	$Q_{open\_water,t}$	[m³/s]	Discharge open water surface (formula 2-b)
Model parameters	$C_{NH4-N,precipitation,t}$	[mg N/l]	Ammonium-N concentration of precipitation
	$C_{NO3-N,precipitation,t}$	[mg N/l]	Nitrate concentration of precipitation
Output	$S_{NH4-N,open\_water,t}$	[g N/s]	Ammonium-N load of open water surface
	$S_{NO3-N,open\_water,t}$	[g N/s]	Nitrate load of open water surface

In the drainage system all sorts of processes occur, such as nitrification and denitrification, which influence the actual ammonium and nitrate contents in the canals. This aspect is described in the flow model and, therefore, is outside the scope of the precipitation runoff model.

In addition to nitrate and ammonium, also organic fixed nitrogen may be supplied with rain water. Rain water often contains a considerable amount of suspended solids. In this phase of the development, organic fixed nitrogen is, however, left out of consideration. Organic fixed nitrogen can be taken into account by the user in the concentration of the precipitation term.

Phosphor

The same assumptions as for nitrogen are applicable to phosphor. This means that the load is directly proportional to the flow. The phosphor load may, therefore, also be described in accordance with a zero order relation:

$$S_{P-total,open\_water,t} = Q_{open\_water,t} \cdot C_{P-total,precipitation,t} \quad (4)$$

Input	$Q_{open\_water,t}$	[m³/s]	Discharge open water surface (formula 2-b)
Model parameters	$C_{P-total,precipitation,t}$	[mg P/l]	Phosphor concentration of precipitation
Output	$S_{P-total,open\_water,t}$	[g P/s]	Phosphor load of open water surface

Target values

The composition of rain water is reasonably known (Landelijk Regenwater meetnet [national rain water measuring network] of KNMI/RIVM). In table 3, the contents of ammonium, nitrate and total phosphor in the precipitation are reflected (v.d. Meent et al., 1985). From these figures extensive spread of the measuring values appears. Possibly more specific measuring data are available per location [A factor 0.014 applies to the conversion of μ mol/l to mg N/l].

Table 3: Overview of the average concentrations of precipitation (v.d. Meent et al. 1985)

	Ammonium-N (mg N/l)	Nitrate-N (mg N/l)	Phosphor (mg P-total/l)
Median	2.4	1.2	0.11
Minimum	1.3	0.90	0.06
Maximum	6.1	1.8	0.27

4.3 Paved surface

4.3.1 Determination effective precipitation

The losses occurring in case of paved surfaces, consist of moistening and evaporation of the wet surface. These losses have been put equal to the open water evaporation and will be minor in general.

$$P_{N,paved,t} = P_{b,t} - f_0 E_{r,t} \quad \text{if} \quad P_{b,t} \geq f_0 E_{r,t} \quad (5\text{-a})$$

$$P_{N,paved,t} = 0 \quad \text{if} \quad P_{b,t} < f_0 E_{r,t} \quad (5\text{-b})$$

Input	$P_{b,t}$ $E_{r,t}$	[mm/day] [mm/day]	Precipitation intensity Reference vegetation evaporation Makkink
Model parameters	f_0^*	[-]	Vegetation factor Makkink for open water
Output	$P_{N,paved,t}$	[mm/day]	Drainable precipitation paved surface

* The crop factor for open water is equal to E_0 / E_R in which E_0 is the open water evaporation according to Penmann. the factor varies somewhat but may approximately be equated with 1.25 (Cultuurtechnisch Vademecum, 1988)

4.3.2 Description of the Hydrograph

The discharge of paved surface is divided into two subflows:

1. Paved surface draining directly through the drainage system;
2. Surface draining through a separated sewer system.

The runoff of both subflows are determined with an singular linear reservoir. A singular linear reservoir was chosen because of the relatively short reaction time.

$$q_{sewer,t} = q_{sewer,t-1} e^{-\Delta t / k_s} + P_{N,paved,t}(1 - e^{-\Delta t / k_s}) \qquad (6\text{-a})$$

$$q_{paved,t} = q_{paved,t-1} e^{-\Delta t / k_p} + P_{N,paved,t}(1 - e^{-\Delta t / k_p}) \qquad (6\text{-b})$$

$$Q_{paved,t} = a(A_{sewer} q_{sewer,t} + A_{paved} q_{paved,t}) \qquad (6\text{-c})$$

Input	$q_{sewer,t}^*$ $q_{paved,t-1}^*$ $P_{N,paved,t}$ A_{sewer}^{**} A_{paved}^{***}	[mm/day] [mm/day] [mm/day] [ha] [ha]	Specific discharge separated sewer system (formula 6-a) Specific discharge paved surface (formula 6-b) Effective precipitation paved surface (formula 5) Separated sewer surface Paved surface
Model parameters	k_s k_p Δt a^{****}	[day] [day] [day] [-]	Time constant reservoir separated sewer system Time constant reservoir paved surface Time step Conversion factor units
Output	$Q_{N,paved,t}$	[m³/s]	Discharge paved surface

* For $q_{sewer,t-1}$ and $q_{paved,t-1}$ at point of time t = 0 a value of 0 is taken

** Paved surface that discharges through a separated sewer system

*** Paved surface that discharges directly into open water

**** The conversion rate is equal to 10/(24 * 3600)

Target value time constant

The time constant is a measure of the velocity with which the precipitation is discharged . In case of paved surface a value of 0.0014 à 0.002 days is generally taken (Cultuurtechnisch Vademecum, 1988). If measured values are available, it is more accurate to derive the time constant from the tail course of the measured discharges. This concerns both the time constant for the reservoir for the separated sewer system as for the paved surface.

4.3.3 Description of water quality

Nitrogen

The discharge of paved surface originates from roofs and roads and is discharged through drain pipes or through a(n) (improved) separated sewer system into the drainage system. It is also applicable to this drainage that hardly any processes occur that influence the N concentrations. The nitrogen load may, therefore, also be described in accordance with a zero order relation. However, it is indeed applicable to this drainage that organic fixed nitrogen may be a factor of importance. Therefore, an equation has been included for this. The discharge is described by the following formulas:

$$S_{NH4-N,paved,t} = Q_{paved,t} \times C_{NH4-N,paved,t} \quad (7\text{-a})$$

$$S_{NO3-N,paved,t} = Q_{paved,t} \times C_{NO3-N,paved,t} \quad (7\text{-b})$$

$$S_{org-N,paved,t} = Q_{paved,t} \times C_{org-N,paved,t} \quad (7\text{-c})$$

Input	$Q_{paved,t}$	[m³/s]	Discharge paved surface (formula 6-c)
Model parameters	$C_{NH4-N,paved,t}$	[mg N/l]	Ammonium-N concentration runoff paved surface
	$C_{NO3-N,paved,t}$	[mg N/l]	Nitrate concentration runoff paved surface
	$C_{org-N,paved,t}$	[mg N/l]	Organic nitrogen in runoff paved surface
Output	$S_{NH4-N,paved,t}$	[g N/s]	Ammonium load of paved surface
	$S_{NO3-N,paved,t}$	[g N/s]	Nitrate load of paved surface
	$S_{org-N,paved,t}$	[g N/s]	Organic nitrogen in runoff paved surface

In the first version of the precipitation runoff module, the term organic fixed nitrogen has not been included.

Phosphor

Also for phosphor the concentration of the discharge may be taken as a constant. The timeframe between precipitation and discharge is short, so that the influence of reaction processes is zero.

$$S_{P,total,paved,t} = Q_{paved,t} \times C_{P-total,paved,t} \quad (8)$$

Input	$Q_{paved,t}$	[m³/s]	Discharge paved surface (formula 6-c)
Model parameters	$C_{P-total,paved,t}$	[mg P/l]	Phosphor concentration runoff paved surface
Output	$S_{P-total,paved,t}$	[g P/s]	Phosphor load of paved surface

Target values

The quality of the discharge from paved surface is determined to a large degree by the function of the area. The Nationale Werkgroep Riolering en Waterkwaliteit (1986) distinguishes the following main functions:

- Residential areas;
- Commercial areas (shops, offices, catering companies, secondary housing function);
- Roads;
- Industrial areas.

The quality of the discharged precipitation also depends on the type of sewer system. The water quality in case of an improved separated sewer system will be different from a separated sewer system. If the lower discharge amounts of improved separated sewer system are taken into account, it is acceptable to use the same target values for the concentrations.

The concentration of pollution in the discharge from paved surface fluctuates strongly. In table 4 the bandwidth between which the concentrations vary are indicated.

Table 4: Overview target value pollution concentrations runoff paved surface (Nationale Werkgroep Rioleringen en Waterkwaliteit, 1986)

	Residential Areas	Commercial Areas	Roads	Industrial Areas
Ammonium (mg N/l)	0.15-2.5	0.03	0.13-2.5	1.2-6.9
Nitrate (mg N/l)	0.1-0.7	0.2-0.5	0.28-1.4	5
Total Phosphate (mg P/l)	0.22-1.5	0.1-0.6	0.05-0.48	-
N-Kjeldahl (mg N/l)	1.5-3.6	0.7-1.1	0.68-5.1	1.2-200

4.4 Unpaved surface

For the runoff of unpaved surface, three processes were distinguished:

1. Infiltration into the soil moisture (unsaturated zone)
2. Percolation into the ground water (saturated zone)
3. Ground water discharge into the drainage system.

These processes are distinguished in the precipitation runoff module also. This set-up is reflected in figure 10.

4.4.1 Infiltration into the soil moisture (unsaturated zone)

First, the infiltration into the unsaturated zone is determined. In addition, the storage in the surface depressions and possibly occurring surface runoff are determined. These aspects are addressed below point by point:

- Infiltration;
- Storage in surface depressions
- Surface runoff

The amount of precipitation that infiltrates is determined by the infiltration capacity of the soil. If the precipitation intensity surpasses the infiltration capacity, the remaining part of the precipitation will be stored on the surface level in the surface depressions. If the maximum storage in the surface depression is surpassed, the extra precipitation will runoff over the surface (surface runoff).

Infiltration

In the design the point of departure is a constant infiltration capacity. This is further explained at the target values for the infiltration capacity. The infiltration intensity is calculated for the time interval from point of time t-1 to t. The precipitation intensity during the time interval is added to the storage existing in surface depressions at the start of the time interval (formula 9-a). When the precipitation intensity and the storage in the surface depressions surpasses the infiltration capacity, the infiltration capacity is set equal to the infiltration capacity (formula 9-b).

$$I_t = P_{b,t} + \frac{B_{t-1}}{\Delta t} \quad \text{if} \quad P_{b,t} + \frac{B_{t-1}}{\Delta t} \le I_{max} \qquad (9\text{-a})$$

$$I_t = I_{max} \quad \text{if} \quad P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \qquad (9\text{-b})$$

A specific situation occurs when the unsaturated zone approaches saturation. The maximum percolation out of the soil moisture reservoir instead of the infiltration capacity becomes critical for this situation (formula 9-c, see also section 2.3.4.2).

$$I_t = \Phi_{pF=0} - \Phi_{t-1} + P_{perc,max} \quad \text{if} \quad \Phi_{t-1} + I_t - P_{perc,max} > \Phi_{pF=0} \qquad (9\text{-c})$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	B_{t-1} *	[mm]	Storage in surface depressions (formula 10)
	I_{t-1} **	[mm/day]	Infiltration intensity (formula 9)
	Φ_{t-1} ***	[mm]	Actual moisture storage (formula 14)
Model Parameters	I_{max}	[mm/day]	Infiltration capacity
	Δt	[day]	Time step
	$P_{perc,max}$	[mm]	Percolation to the saturated zone at pF=0
	$\Phi_{pF=0}$	[mm]	Moisture storage if pF=0
Output	I_t	[mm/day]	Infiltration intensity

* For B_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation without storage in surface depressions.

** For I_{t-1} at point of time t=0, a value of 0 is taken, equalling a situation without infiltration.

*** For Φ_{t-1} at point of time t=0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined form the Staring Series).

Storage in the surface depressions

When the precipitation intensity surpasses the infiltration intensity, the water stays behind on the surface level and is stored in surface depressions. This storage in surface depressions depends strongly on the roughness of the ground. The storage at point of time t is determined with a water balance for the storage in surface depressions. For this purpose the precipitation intensity minus the infiltration intensity during time interval t-1 to t is added to the storage present in the surface depressions at the start of the time interval (point of time t-1). No water remains in the surface depressions when this volume is smaller than the infiltration capacity (formula 10-a). When this volume surpasses the infiltration capacity, water is stored in the surface depressions (formula 10-b). Surface runoff will occur when the amount in the surface depressions surpasses the maximum storage (formula 10-c).

$$B_t = 0 \quad \text{if} \quad P_{b,t} + \frac{B_{t-1}}{\Delta t} \le I_{max} \tag{10-a}$$

$$B_t = (P_{b,t} - I_t)\,\Delta t + B_{t-1} \quad \text{if} \quad P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \text{ and} \tag{10-b}$$

$$\text{if} \quad (P_{b,t} - I_t)\Delta t + B_{t-1} \le B_{max}$$

$$B_t = B_{max} \quad \text{if} \quad P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \text{ and} \tag{10-c}$$

$$\text{if} \quad (P_{b,t} - I_t)\Delta t + B_{t-1} > B_{max}$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	I_t	[mm/day]	Infiltration intensity (formula 9)
	B_{t-1} *	[mm]	Storage in surface depressions (formula 10)
Model Parameters	I_{max}	[mm/day]	Infiltration capacity
	B_{max}	[mm]	Maximum storage in surface depressions
	Δt	[day]	Time step
Output	B_t	[mm/day]	Storage in surface depressions

* For B_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation without storage in surface depressions

Surface runoff

The amount of precipitation that runs off as surface runoff, depends on the infiltration capacity of the soil, the precipitation intensity and the storage in surface depressions. When the amount of storage in surface depressions surpasses the maximum storage, surface runoff occurs.

$$P_{N,sur,t} = P_{b,t} + \frac{B_t}{\Delta t} - I_t - \frac{B_{max}}{\Delta t} \quad \text{if:} \quad \left(P_{b,t} - I_t\right)\Delta t + B_{t-1} > B_{max} \tag{11-a}$$

$$P_{N,sur,t} = 0 \quad \text{if:} \quad \left(P_{b,t} - I_t\right)\Delta t + B_{t-1} \le B_{max} \tag{11-b}$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	I_t	[mm/day]	Infiltration intensity (formula 9)
	B_{t-1} *	[mm]	Storage in surface depressions (formula 10)
Model Parameters	I_{max}	[mm/day]	Infiltration capacity
	B_{max}	[mm]	Maximum storage in surface depressions
	Δt	[day]	Time step
Output	$P_{N,sur,t}$	[mm/day]	Effective precipitation surface runoff unpaved surface

* For B_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation without storage in surface depressions

In this section the effective precipitation for the surface runoff is described. The hydrograph is further described in section 2.3.4.3.

The evaporation from the surface depressions has not been included. The evaporation is indeed included as evapotranspiration from the unsaturated zone in the soil moisture reservoir. By neglecting the evaporation from surface depressions a slight error is introduced in general.

Target Values infiltration capacity

The velocity of infiltration depends on the intensity and the duration of the precipitation, type of soil, land use, and soil moisture content at the start of the shower. During a shower with a constant intensity, the infiltration velocity decreases exponentially from a maximum value f_0 at the start of the shower to an constant value f_c. This value is reached when the soil reaches the field capacity (see figure 12). Various formulas have been developed to determine the infiltration capacity of a type of soil.

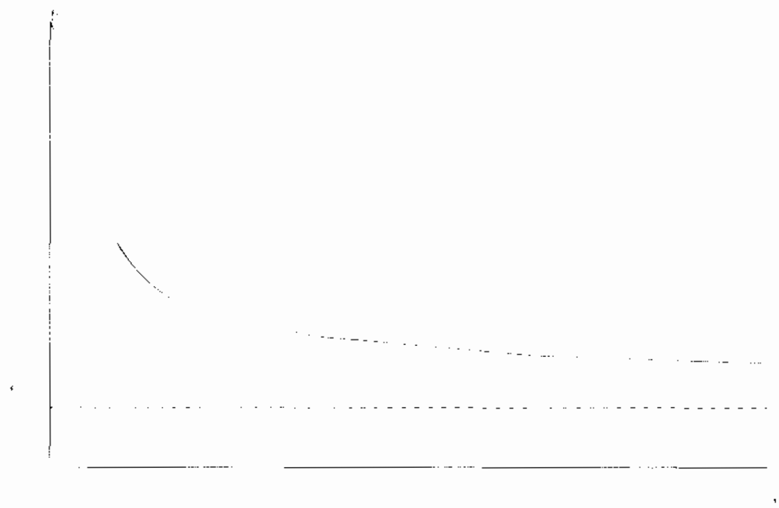


figure 12: Infiltration velocity

In the precipitation runoff module the precipitation runoff process is described at a catchment area level. An average value for the infiltration intensity in the catchment area will have to be entered. The infiltration intensity will, however, vary widely per location, due to variation in vegetation and type of soil. In addition, the infiltration intensity will vary in time and will decrease to a constant value when reaching the field capacity (pF = 2). Generally, the constant infiltration intensity as outlined in figure 12 will be reached within one day. This value is named as the infiltration capacity.

No infiltration formulas have been included in the precipitation runoff module. The user may enter an infiltration capacity for the catchment area involved, which is constant in time. The error introduced by this will be minor in case of time steps of one day or larger. Table 5 gives an overview of the values found in the literature.

Table 5: Target values infiltration capacity

Texture*	**Infiltration capacity** after much rain**
Sand (Wyseure and Feyen, 1982)	7.6-11.4 mm/hour
Finer texture	3.8-7.6 mm/hour
Very fine/disturbing layers	1.3-3.8 mm/hour
Impervious/clay with swelling	0.0-1.3 mm/hour
Saturated clay soil (BUIBAK, 1994)	approximately 4 mm/hour
Loamy and peaty soil	8 mm/hour
Very pervious sand	approximately 12 mm/hour

* The texture classes are copied from the literature.
** The infiltration capacity is expressed in [mm/day] instead of [mm/hour]

Target values maximum storage in surface depressions
The maximum storage in surface depressions depends on the roughness of the terrain and the degree of vegetation. Representative target values for the maximum storage in surface depression are difficult to give, in view of the wide variety of these parameters within areas. Based on the roughness and vegetation on the ground, an estimate will have to be made for this value. In general, the choice of this value will hardly influence the model results, because a situation in which the maximum storage in surface depressions occurs, hardly takes place in the Dutch situation.

4.4.2 Percolation into the ground water (saturated zone)

The percolation into the ground water is described by means of a soil moisture reservoir. A water balance of the amount of moisture in the unsaturated zone is maintained in the soil moisture reservoir. The replenishment of soil moisture in the unsaturated zone or the inflow of the soil moisture reservoir is the infiltration calculated by the model. The outflows are the evapotranspiration and the effective precipitation (the precipitation that runs off through drains or ground water). The principle of the soil moisture reservoir is reflected in figure 11.

In the precipitation runoff module, capillary rise from the ground water to the unsaturated zone has not been included. Furthermore, it has been assumed that the infiltration immediately results in percolation. The occurring slowing down is ignored. This results in errors in the calculated evapotranspiration and the percolation.

Evapotranspiration relation
The potential evapotranspiration is determined based on the reference crop evapotranspiration and a crop factor. The crop factor is a measure for the transpiration of the crop and depends on the type of crop and the growth stage (function of time). If the crop has not been supplied with water in an optimum way, the actual evapotranspiration is smaller than the potential evapotranspiration. A simple relation between the actual evapotranspiration and the actual moisture storage is included (evapotranspiration relation). It has been assumed that in case of water contents larger than those in case of field capacity, the actual evapotranspiration is equal to the potential evapotranspiration. Between the moisture storage at field capacity and the wilting point, the actual

evapotranspiration decreases linearly from the potential evapotranspiration at field capacity to zero at the wilting point. It has been assumed that no moisture is available to the vegetation at the wilting point.

$$E_{a,t} = f\, E_{r,t} \qquad \text{if} \qquad \Phi_{pF=0} \geq \Phi_{t-1} > \Phi_{pF=2} \qquad (12\text{-a})$$

$$E_{a,t} = \frac{(\Phi_{t-1} - \Phi_{pF=4.2})}{(\Phi_{pF=2} - \Phi_{pF=4.2})} f\, E_{r,t} \qquad \text{if} \qquad \Phi_{pF=2} \geq \Phi_{t-1} \geq \Phi_{pF=4.2} \qquad (12\text{-b})$$

$$E_{a,t} = 0 \qquad \text{if} \qquad \Phi_{t-1} < \Phi_{pF=4.2} \qquad (12\text{-c})$$

Input	Φ_{t-1} *	[mm]	Actual moisture storage (formula 14)
	$E_{r,t}$	[mm/day]	Reference crop evapotranspiration Makkink
Model Parameters	$\Phi_{pF=2}$	[mm]	Moisture storage if pF=2
	$\Phi_{pF=4.2}$	[mm]	Moisture storage if pF=4.2
	f	[-]	Crop factor Makkink
Output	$E_{a,t}$	[mm/day]	Actual evapotranspiration

* For Φ_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined from the Staring series)

Percolation relation

The percolation to the ground water depends on the water content in the unsaturated zone. In the precipitation runoff module, a simple relation between the percolation and the actual moisture storage (percolation relation) has been included. It has been assumed that in case of saturation, the percolation is equal to the maximum percolation. Between the moisture storage saturation and at field capacity, the percolation decreases linearly from the maximum percolation at saturation to zero at field capacity. It has been assumed that no moisture is available for percolation at the wilting point.

$$P_{perc,t} = \frac{(\Phi_{t-1} - \Phi_{pF=2})}{(\Phi_{pF=0} - \Phi_{pF=2})} P_{perc,\max} \qquad \text{if} \qquad \Phi_{pF=0} \geq \Phi_{t-1} > \Phi_{pF=2} \qquad (13\text{-a})$$

$$P_{perc,t} = 0 \qquad \text{if} \qquad \Phi_{t-1} \leq \Phi_{pF=2} \qquad (13\text{-b})$$

Input	Φ_{t-1} *	[mm]	Actual moisture storage (formula 14)
	I_t	[mm/day]	Infiltration intensity (formula 9)
Model Parameters	$\Phi_{pF=0}$	[mm]	Moisture storage if pF=0
	$\Phi_{pF=2}$	[mm]	Moisture storage if pF=2
	$\Phi_{pF=4.2}$	[mm]	Moisture storage if pF=4.2
	$P_{perc,\max}$	[mm/day]	Percolation to the saturated zone that occurs between pF=0 and pF=2 (maximum)
Output	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone

* For Φ_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined from the Staring series)

Water balance soil moisture reservoir

In the water balance, both the evaporation and the percolation depend on the actual soil moisture content. The change in the soil moisture content is described with the differential equation:

$$\frac{\partial\Phi}{\partial t} = I_t - E_{a,t}(\Phi) - P_{perc,t}(\Phi)$$

The equation is solved explicitly. At point of time t-1 the condition of the soil moisture reservoir is expressed in the moisture storage Φ_{t-1}. Based on the actual moisture storage at point of time t-1, the evapotranspiration and percolation are calculated for the time interval from point of time t-1 to t. Based on the calculated evapotranspiration and percolation, the actual moisture storage at point of time t is calculated (Φ_t)

$$\Phi_t = \Phi_{t-1} + (I_t - E_{a,t} - P_{perc,t})\,\Delta t \qquad (14)$$

Input	Φ_{t-1} *	[mm]	Actual moisture storage (formula 14)
	I_t	[mm/day]	Infiltration intensity (formula 9)
	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 13)
	$E_{a,t}$	[mm/day]	Actual evapotranspiration (formula 12)
Model Parameters	Δt	[day]	Time step
Output	Φ_t	[mm]	Actual moisture storage

* For Φ_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined from the Staring series)

Disadvantage of an explicit solution is the risk of instable calculations, occurring with large time steps or a relatively small content of the soil moisture reservoir. In case of instable calculation, the user should define smaller time steps.

The moisture storage in the soil moisture reservoir varies between the minimal moisture storage at wilting point and the maximal moisture storage at saturation. For moisture storage values smaller than at wilting point, no evaporation occurs (formula 12-c), for values larger than the at saturation the percolation is set equal to the infiltration capacity (formula 13-a).

Target values crop factor Makkink

The crop factor depends on the type of overgrowth and the growth stage. In appendix A an overview is given of the crop factors for various crop types. The crop factor for a catchment area is determined as the mean crop factor per percentage of the surface for the different crops in the catchment area.

Target values moisture storage
In the formulas 13 and 14, the moisture storage at field capacity (pF=2) and at the wilting point (pF=4.2) need to be entered. The moisture storage in the unsaturated zone is derived from the soil moisture content and the location of the ground water level compared to the surface level. It is remarked that the moisture storage depends on the location of the ground water level. In polder areas slight fluctuations in the ground water level occur in general. In sandy soils more fluctuations occur, so that also the moisture storage will vary.

In the Staring series, the soil moisture characteristics for various types of soils are determined. This is a relation between the pF value (logarithm of the negative pressure head) and the soil moisture content. Based on the Staring series, the water content at field capacity and at the wilting point may be determined for the various types of soils. In appendix B a summary of the Staring series is given.

Therefore, the following method may be used to determine the moisture storage:

- The length between the average surface level and the average ground water level or water level in the drainage system is estimated. This length is assumed being constant during the simulation period (for example 0.8 m);
- The soil moisture content is determined for the dominating type of soil at saturation level (pF=0), at field capacity level (pF=2) and at the wilting point (pF=4.2). These values are recorded in the Staring series (see appendix B) for the most common types of soil. As an example, the values for 'loamy-poor, very fine to moderately fine sand' are 37.1 volume percent (pF=0), 20.1 volume percent (pF=2) and 3 volume percent (pF=4.2).
- The moisture storage is determined as the product of the length of the unsaturated zone and the volume fraction. In the example above this would be:

  - $\Phi_{pF=0} = 0.371 \times 0.8m = 296.8mm$
  - $\Phi_{pF=2} = 0.201 \times 0.8m = 160.8mm$
  - $\Phi_{pF=4.2} = 0.003 \times 0.8m = 24mm$

Target value maximum percolation
The maximum percolation is the percolation at saturation. Mostly the infiltration capacity is taken as target value for the maximal percolation. Table 5 gives an overview of the target values for the infiltration capacity.

4.4.3 Ground water discharge into the drainage system

The discharge from unpaved surface is built up by various runoff processes. The interflow and the drainage have not been described separately, but jointly form the quick ground water runoff. Within the design the following aspects are distinguished:

- Surface runoff;
- Quick component of the ground water discharge;
- Slow component of ground water discharge.

Surface runoff
This discharge is described with one linear reservoir, equal to the description for discharge of open water (the discharge of the water across the surface level to open water takes place relatively quickly).

$$q_{sur,t} = q_{sur,t-1}\, e^{\frac{-\Delta t}{k_{sur}}} + P_{N,sur,t}\left(1 - e^{\frac{-\Delta t}{k_{sur}}}\right) \qquad (15\text{-a})$$

$$Q_{sur,t} = a\, A_{unpaved}\, q_{sur,t} \qquad (15\text{-b})$$

Input	$q_{sur,t-1}$ *	[mm/day]	Specific surface runoff unpaved surface (formula 15-a
	$P_{N,sur,t}$	[mm/day]	Effective precipitation surface runoff unpaved surface (formula 11)
	$A_{unpaved}$	[ha]	Unpaved surface
Model Parameters	k_{sur}	[day]	Time constant reservoir surface runoff unpaved surface
	Δt	[day]	Time step
	a **	[-]	Conversion factor units
Output	$P_{sur,t}$	[m³/s]	Surface runoff unpaved surface

* For $q_{sur,t-1}$ at point of time t = 0, a value of 0 is taken

** The conversion factor is equal to 10/(24 * 3600)

Target value time constant
The time constant is a measure for the velocity with which the precipitation is discharged. The surface runoff will take place very quickly. As target value a value of 0.0014 á 0.002 days may be taken, equalling the time constant of paved surface (Cultuurtechnisch Vademecum, 1988).

Quick and slow component of the ground water discharge
During the discharge through the saturated zone, a significant slowing down effect occurs because of resistances in the soil. This process is described by a configuration of linear reservoirs. The quick and slow component of the ground water discharge are described by separate linear reservoirs, of which two possibilities are taken up.

(a) Two parallel Nash-cascades;

(b) Combination of Nash-cascades and Krayenhoff van de Leur

ad (a) two parallel Nash-cascades
In this option, the discharge is divided into a quick and a slow component ground water runoff by means of a distribution code. The percolation calculated will partly runoff through a slow component (βP_{perc}) and partly through a quick component ($[1-\beta]P_{perc}$). The hydrographs of both the quick and slow ground water discharge are described by a series of linear reservoirs (see figure 11). By entering the time constant and the number of reservoirs, the user may enter the properties of the discharge process. In the precipitation runoff module, a default value of one has been taken for the number of reservoirs.

The quick and slow ground water discharges are described by the following formulas:

For the 1[st] reservoir:

$$q_{quick,1,t} = q_{quick,1,t-1}\, e^{\frac{-\Delta t}{k_q}} + (1-\beta) P_{perc,t} (1 - e^{\frac{-\Delta t}{k_q}}) \qquad (16\text{-a})$$

For i is the 2[nd] unto and including the m[th] reservoir:

$$q_{quick,i,t} = q_{quick,i,t-1}\, e^{\frac{-\Delta t}{k_q}} + q_{quick,i-1,t} (1 - e^{\frac{-\Delta t}{k_q}}) \qquad (16\text{-b})$$

For the 1[st] reservoir:

$$q_{slow,1,t} = q_{slow,1,t-1}\, e^{\frac{-\Delta t}{k_s}} + \beta P_{perc,t} (1 - e^{\frac{-\Delta t}{k_s}}) \qquad (16\text{-c})$$

For i is the 2[nd] upto and including the n[th] reservoir:

$$q_{slow,i,t} = q_{slow,i,t-1}\, e^{\frac{-\Delta t}{k_s}} + q_{slow,i-1,t} (1 - e^{\frac{-\Delta t}{k_s}}) \qquad (16\text{-d})$$

$$Q_{quick,t} = a\, A_{unpaved}\, q_{quick,m,t} \qquad (16\text{-e})$$

$$Q_{slow,t} = a\, A_{unpaved}\, q_{slow,n,t} \qquad (16\text{-f})$$

Input	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 13)
	$q_{slow,i,t-1}$ *	[mm/day]	Specific slow component ground water discharge unpaved surface (formula 16)
	$q_{quick,i,t-1}$ *	[mm/day]	Specific quick component ground water discharge unpaved surface (formula 16)
	$A_{unpaved}$	[ha]	Unpaved surface
Model Parameters	β	[-]	Distribution code quick and slow components ground water discharge
	k_s	[day]	Time constant reservoir slow component ground water discharge
	k_q	[day]	Time constant reservoir quick component ground water discharge
	m	[-]	Number of reservoirs quick component ground water discharge
	n	[-]	Number of reservoirs slow component ground water discharge
	Δt	[day]	Time step
	a **	[-]	Conversion factor units
Output	$Q_{slow,t}$	[m³/s]	Drainage slow component ground water discharge
	$Q_{quick,t}$	[m³/s]	Drainage quick component ground water discharge.

* For $q_{slow,i,t-1}$ and $q_{quick,i,t-1}$ at point of time t = 0, a value of 0 is taken for all reservoirs i=1 - n and i=1-m

** The conversion rate is equal to 10/(24 * 3600)

ad (b) combination Nash-cascade and Krayenhoff van de Leur

In this option the discharge is also divided into a quick and a slow component ground water discharge, by means of a distribution code. The hydrograph of the quick ground water discharge is described in this option by a number of parallel linear reservoirs (Krayenhoff van de Leur). The slow ground water runoff is described by a series of linear reservoirs (see figure 11). A default value of one has been taken for the number of reservoirs in a series.

The quick and slow components of the ground water discharge is described by the following formulas:

For i is the 1st unto and including the dth reservoir:

$$q_{quick,i,t} = (1-\beta) * \{ \frac{1}{\left(\sum_{j=1,3,5...}^{(2d-1)} \frac{1}{j^2} \right)} P_{perc,t} \frac{1}{(2i-1)^2} (1-e^{\frac{-\Delta t(2i-1)^2}{k_q}}) \} + q_{quick,i,t-1} e^{\frac{-\Delta t(2i-1)^2}{k_q}} \quad (17\text{-a})$$

For the 1st reservoir:

$$q_{slow,1,t} = q_{slow,1,t-1} e^{\frac{-\Delta t}{k_s}} + \beta P_{perc,t} (1-e^{\frac{-\Delta t}{k_s}}) \quad (17\text{-b})$$

For i is the 2nd upto and including the nth reservoir:

$$q_{slow,i,t} = q_{slow,i,t-1} e^{\frac{-\Delta t}{k_s}} + q_{slow,i-1,t} (1-e^{\frac{-\Delta t}{k_s}}) \quad (17\text{-c})$$

$$Q_{quick,t} = a\, A_{unpaved} \left(\sum_{i=1}^{d} q_{quick,i,t} \right) \quad (17\text{-d})$$

$$Q_{slow,t} = a\, A_{unpaved}\, q_{slow,n,t} \quad (17\text{-e})$$

Input	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 13)
	$q^*_{slow,i,t-1}$	[mm/day]	Specific slow component ground water discharge unpaved surface (formula 17)
	$q^*_{quick,i,t-1}$	[mm/day]	Specific quick component ground water discharge unpaved surface (formula 17)
	$A_{unpaved}$	[ha]	Unpaved surface

Model Parameters	β	[-]	Distribution code quick and slow components ground water discharge
	k_s	[day]	Time constant reservoir slow component ground water discharge
	k_q	[day]	Time constant reservoir quick component ground water discharge
	d^{**}	[-]	Number of reservoirs quick component ground water discharge
	n	[-]	Number of reservoirs slow component ground water discharge
	Δt	[day]	Time step
	a^{***}	[-]	Conversion factor units
Output	$Q_{slow,t}$	[m³/s]	Discharge slow component ground water discharge
	$Q_{quick,t}$	[m³/s]	Discharge quick component ground water discharge.

* For $q_{slow,i,t-1}$ and $q_{quick,i,t-1}$ at point of time t = 0, a value of 0 is taken for all reservoirs i=1 - n and i=1 - m

** The Krayenhoff van de Leur model describes an infinite number of reservoirs. This is discreticised to a finite number of reservoirs. Each next reservoir empties quicker and processes a smaller part of the precipitation. The target value for the number of reservoirs is 5 reservoirs.

*** The conversion factor is equal to 10/(24 * 3600)

Target values time constant

The target values for the time constant of linear reservoirs are derived from measured hydrographs. The target values for the Krayenhoff van de Leur model are given in table 6. Since catchment areas are mostly not homogeneous, the time constant can be calculated as the weight mean time constant per percentage of the surface.

The target values as presented in table 6 can not be used at once. The precipitation runoff module is extended compared to the Krayenhoff van de Leur model. It distinguishes paved and unpaved surface, so the time constant is specified for each type of surface, where the time constant for the unpaved surface only describes the discharge processes for unpaved surface. The time constant in the Krayenhoff van de Leur model only describes the full surface (paved and unpaved surface). In addition, the precipitation runoff model describes part of the slowing down in the soil moisture reservoir. This has consequences for the time constant to be used for the linear reservoirs. The target values can therefore be used as start values, but calibration of the values with measured discharges remains essential.

An other way to derive the time constant is from measured hydrographs. This is the most direct and accurate way to estimate the time constant. In addition, the time constant of both the quick and slow component of the ground water discharge can be estimated separately. The quick component is estimated from the hydrograph of discharge peaks, whereas the slow component is estimated from the hydrograph during low discharges.

Table 6: Target values for the Krayenhoff van de Leur model

k [days]	Drainage type
0.0014 - 0.002	Discharge of 1000-4000 m^2 paved surface
0.005 - 0.01	Surface runoff on strongly sloping ground
0.1 - 1	Surface runoff, runoff of grounds with impervious layers at a very shallow depth
1.5 - 3	Runoff of well-drained farmland
15 - 30	Badly drained grassland with overgrown ditches (swamp runoff)
300 - 2000	Discharge of seepage from high, very pervious grounds (Veluwe, Zuid-Limburg)

Target values configuration linear reservoirs

The precipitation runoff module distinguishes a quick and slow component of the ground water discharge. The user defines the number of reservoirs and the distribution code related to the application.

For rather simple applications, it is not particularly necessary to distinguish a quick and slow component of the ground water discharge. The ground water discharge is described by a single component with a single linear reservoir and a value for the distribution factor of 0 or 1.

For more detailed applications, however, it is recommended to distinguish a quick and slow component of the ground water discharge. It is not possible to give target values for the distribution factor. This factor should therefore be calibrated on measured hydrographs simultaneously to the time constants (see target values time constant).

In the Nash-cascade, the number of reservoirs in series must be entered. The default is one reservoir. In case of large catchment areas, extra travel time may be created by entering several reservoirs.

The model Krayenhoff van de Leur theoretically describes an infinite number of reservoirs. In the precipitation runoff module, the model is discreticised into a finite number of reservoirs, in which each next reservoir empties quicker but processes a smaller part of the precipitation. In case of a number of reservoirs of 5, the error introduced is negligible.

4.4.4 Description water quality

The description of the water quality is based on the discharge processes distinguished for the determination of the hydrograph, surface runoff, quick and slow component of discharge (see section 2.3.4.2).

4.4.4.1 Surface runoff

Nitrogen

The surface runoff is formed by precipitation that runs off directly across the surface level. In this case, reaction processes occur to a lesser degree. Therefore, the load is described by an a zero order relation.

$$S_{NH4-N,sur,t} = Q_{sur,t} * C_{NH4-N,sur,t} \quad (18\text{-a})$$

$$S_{NO3-N,sur,t} = Q_{sur,t} * C_{NO3-N,sur,t} \quad (18\text{-b})$$

$$S_{org-N,sur,t} = Q_{sur,t} * C_{org-N,sur,t} \quad (18\text{-c})$$

Input	$Q_{sur,t}$	[m³/s]	Surface runoff unpaved surface (formula 15-b)
Model Parameters	$C_{NH4-N,sur,t}$ $C_{NO3-n,sur,t}$ $C_{org-N,sur,t}$	[mgN/l] [mg N/l] [mg N/l]	Ammonium-N concentration surface runoff unpaved surface Nitrate concentration surface runoff unpaved surface Organic nitrogen concentration surface runoff unpaved surface
Output	$S_{NH4-N,sur,t}$ $S_{NO3-N,sur,t}$ $S_{org-N,sur,t}$	[g N/s] [g N/s] [g N/s]	Ammonium load surface runoff unpaved surface Nitrate load surface runoff unpaved surface Organic nitrogen load surface runoff unpaved surface

In the first version of the precipitation runoff module the term organically fixed nitrogen has not been included.

Phosphor
The phosphor load is described by a zero order equation just as nitrogen.

$$S_{P-total,sur,t} = Q_{opp,t} * C_{P-total,sur,t} \qquad (19)$$

Input	$Q_{sur,t}$	[m³/s]	Surface runoff unpaved surface (formula 15-b)
Model Parameters	$C_{P-total,sur,t}$	[mg P/l]	Phosphor concentration surface runoff unpaved surface
Output	$S_{P-total,sur,t}$	[g P/s]	Phosphor load surface runoff unpaved surface

Target values
Only few target values are known for the concentrations of surface runoff. The concentration depends very much on the time scale and the ground use. During a longer period, this concentration will approach that of the precipitation. On a small time scale, ground use and fertilisation level are determining factors. The target values as obtained form the literatue are listed in table 7.

4.4.4.2 Quick component of the ground water discharge

The quick ground water discharge consists of precipitation, which is discharged through drain pipes, after infiltration into the ground (see figure 4). Contrary to the slow ground water discharge, this precipitation is buffered to a less degree, before it is discharged. The concentration nutrients is, therefore, often higher and there is more fluctuation.

In case of leaching of nutrient loads, it is relevant to distinguish between various types of ground use, especially between fertilised and non-fertilised surfaces. In case of non-fertilised surfaces the nutrient concentrate profile is much flatter in the vertical direction than in case of fertilised surfaces.

Nitrogen
A factor of influence is the flow rate of effective precipitation. The key question is whether the precipitation can lead to such a thinning that in case of much precipitation, the concentration decreases substantially. In the intermezzo below, a calculation model is worked out, in which is concluded that the influence of the precipitation flow rate has little effect on the N-concentration. At an annual or seasonal level, variances may occur, depending on the fertilisation, etc. However, it is impossible to link these to the amount of precipitation.

INTERMEZZO III: Calculation examples

At 1m surface level is a drainage system that discharges directly into the drainage system under consideration. The average nitrate concentration in the ground moisture is expected to be higher than in the discharged precipitation. Certainly in case of fertilised surfaces with higher concentration in the toplayer, this is the case. In the examples below, a uniform concentration distribution is the point of departure. In this assumption, the leaching of nutrients is equal to the ratio between the amounts of soil moisture and effective precipitation. Runoff of precipitation occurs if the field capacity is reached. Two examples have been worked out, one for sand with a slight field capacity and one for clay with a large field capacity. Drainage takes place at a depth of 1m and the annual effective precipitation is assumed to be 300 mm/y. As maximum supply of precipitation the infiltration capacity of the type of soil is taken. The precipitation is, however, seldom so heavy that this capacity is reached.

Overview of the degree of thinning of the soil moisture

	Field capacity (m^3 soil moisture/m^3)	Infiltration capacity (mm/h)	Maximum thinning of the ground water moisture per hour	Average annual thinning of the ground water moisture
Sand	0.2	12	6%	150%
Clay	0.37-0.45	4	0.8-1%	80%

The thinning on a hourly basis is relatively slight. The concentration course as a result of thinning is, therefore, negligibly small.

In case of fertilised surfaces, an increased concentration in the drained ground water may occur, due to migration of nitrate-rich water from the fertilised toplayer of the soil. The interface between nitrate-rich and nitrate-poor ground water is moving in a vertical direction, until it arrives at the drain pipes. NITSOL calculations (Hopstaken et al., 1987) for sandy soils indicate that nitrate concentrations at a depth of 50-75 cm are relatively constant, in case of a step size of decades. Variances in concentration occur mainly in the topmost 25 cm of the soil. In case of smaller step sizes, for example of hours, the concentration course may be very different. As far as known, on-line measuring has never been carried out regarding surface runoff, for example after a fertilisation period. As a result of lack of information, it is proposed to keep the ammonium and nitrate concentrations constant. This however reduces the accurateness of the model results in case of smaller step sizes.

The relation between the ground water level and the denitrification has been investigated (Steenvoorden, 1983, Bouwmans et al., 1989). The ground water level is classified in ground water steps, which are determined by the average highest and average lowest ground water level (GHG or GLG). The denitrification factor indicates with which factor the leaching of nitrate must be corrected. A situation with very low ground water levels (GtVII*) is taken as a reference. These values are, however, applicable to the total nitrate run off, so that translation for the subflows is difficult.

The nitrate concentration in the quick ground water discharge may be linked to the concentration in the deeper soil layers (slow ground water runoff) by means of denitrification factors.

$$S_{NH4-N,quick,t} = Q_{quick,t} * C_{NH4-N,quick,t} \qquad (20\text{-a})$$

$$S_{NO3-N,quick,t} = Q_{quick},_t * C_{NO3-N,slow,t} / N \qquad (20\text{-b})$$

Input	$Q_{quick,t}$	[m³/s]	Quick component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{NH4-N,quick,t}$	[mgN/l]	Ammonium-N concentration quick component ground water discharge unpaved surface
	$C_{NO3-N,quick,t}$	[mg N/l]	Nitrate concentration slow component ground water discharge unpaved surface
	N	[-]	Denitrification factor
Output	$S_{NH4-N,quick,t}$	[g N/s]	Ammonium load quick component ground water discharge unpaved surface
	$S_{NO3-N,quick,t}$	[g N/s]	Nitrate load quick component ground water discharge unpaved surface

Phosphor

Significant leaching of phosphor may occur when the ground water level rises into the phosphor saturated zone. In general, also the phosphor fixation capacity in the shallow ground layers in The Netherlands is only partly used. The Ministry of VROM indicated a number of areas in The Netherlands, which are sensitive to P leaching. In the remaining areas, the points of departure will be that the phosphor fixation capacity has not been used in this way, an equilibrium exists between the P-complex and solved P, and phosphor does not leach substantially. Areas with a utilisation degree of the phosphor fixation capacity of over 25% are considered phosphor saturated grounds. In these grounds increased P loads may be leached. The relation between P content in the quick component of ground water discharge and the use degree of the phosphor fixation capacity is a point for further investigation.

The P concentrations are not expected to depend strongly on the precipitation flow rate, but do depend on the adsorption/desorption equilibrium. The P load in the soil is in those cases so large that thinning does not play any meaningful part. Also to phosphor a first order equation is applicable. In addition, phosphor may leach, in the form of fine, suspended matter.

$$S_{P-total,quick,t} = Q_{quick,t} * C_{P-total,quick,t} \tag{21}$$

Input	$Q_{quick,t}$	[m³/s]	Quick component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{P-total,quick,t}$	[mg P/l]	Phosphor concentration quick component ground water discharge unpaved surface
Output	$S_{P-total,quick,t}$	[g P/s]	Phosphor load quick component ground water discharge unpaved surface

Target values surface runoff, slow and quick component of the ground water discharge

The concentration of surface runoff, the slow and quick component of the ground water discharge of unpaved surface depend mainly on soil type and land use. Three soil types are distinguished:

- sand
- clay
- peat

The next types of land use are distinguished:

- unfertilised land
- fertilised grassland
- fertilised green maize farmland
- fertilised other farmland

Besides these categories, areas with specific land use can be distinguished such as horticulture or bulb farming. The impact of these types of land use in leaching of nutrients is very specific, due to the specific conditions with regret to fertilisation and water management.

Table 7 lists the target values for the types of discharge, specified for soil type and land use. These values are rough estimates based on incidental measurements found in the literature. The concentrations of nutrients in discharges fluctuate over seasons, degree of fertilization, organic content etc.. It is strongly emphasized that these target values are incidental and therefore not representative for other areas. It is therefore strongly recommended to use measured values within the area of interest as much as possible.

Table 7: Target values concentration nutrients

target values unpaved surface (mg/l)												
soil type	unfertilised land			fertilised grassland			fertilised green maize farmland			fertilised other farmland		
	NO3	NH4	PO4	NO3	NH4	PO4	NO3	NH4	PO4	NO3	NH4	PO4
surface runoff												
sand			0,1--3,2c	5-9,5a		0,1-3,2c 2-4a			0,1-3,2c			0,1-3,2c
clay						1-3a						
peat						2a						
quick component of the ground water discharge												
sand	2d			4b 5-9,5a			3b			2b		
clay	1d											
peat	2d											
slow component of the ground water discharge												
sand	1,5d 0,03-4,3c 21-39a	0,08-,36e	<0,01e	21-39a 43d			21-39a 80c 113d			21-39a 20d		
clay	0,07-0,7e	3,4-13,1e	1,4-6e	53d						14d		
peat	0,2-0,8e	0,9-3,6e	0,10-0,38e									

a Meinardi, 1991

b Drecht, 1986

c Meinardi en van der Valk, 1989 (vastgesteld voor totaal-stroomgebied)

d Steenvoorden et al 1993 (bij GWI en GWVII als totaal-N)

e Bots et al, 1978 (bij ondiep grondwater 2m-maaiveld)

Target values denitrification factor

Table 8 gives an overview of the denitrification factor for the various ground water steps.

Table 8: Overview of the denitrification factors and ground water steps (van Drecht et al., 1991)

Ground water step	GLG (cm-surface level)	GHG (cm-surface level)	Denitrification factor
I	<50	<25	0.04-0.05
II	50-80	>25	0.08-0.1
III	80-120	25-40	0.22-0.31
IV	80-120	40-80	2.00-0.42
V	120-160	<25	0.15-0.5
VI	120-160	40-80	0.22-0.48

VII	160-220	80-140	0.73-0.83
VII'	220-280	140-200	1

4.4.4.3 Slow component of ground water discharge

Nitrogen

Nitrogen may also be discharged eventually through the deeper soil layers into the water course (see figure 4) by means of infiltration and percolation. The slow component of ground water discharge has a relatively long retention time in the soil. In addition, the ground water acts as a buffer, by means of which concentration differences are flattened out to a large extent. This picture is confirmed by calculations of the nitrate concentration by means of the programme NITSOL (Hopstaken et al., 1987). At a depth larger than 2 m, low and constant nitrate degrees are measured. This means that a zero order relation will suffice.

Solved nitrogen mainly occurs in the form of nitrate and ammonium. Ammonium may be nitrificated into nitrate by bacteria in aerobic circumstances. This is denitrified into N_2 in anoxic circumstances (see intermezzo I). In most cases, the denitrification is the velocity determining step in this reaction chain. Only in case of peaty soil with a high organical fraction (carbon source for denitrificating bacteria) and anaerobic conditions in the ground water (no nitrification) the reverse is the case. In view of the long retention time of the water in the ground, there is a stationary situation. This results in zero order relations for the flow rate of the effective precipitation.

$$S_{NH4-N,slow,t} = Q_{slow,t} * C_{NH4-N,slow,t} \qquad (22\text{-a})$$

$$S_{NO3-N,slow,t} = Q_{slow,t} * C_{NO3-N,slow,t} \qquad (22\text{-b})$$

Input	$Q_{slow,t}$	[m³/s]	Slow component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{NH4-N,slow,t}$	[mg N/l]	Ammonium-N concentration slow component ground water discharge unpaved surface
	$C_{NO3-N,slow,t}$	[mg N/l]	Nitrate concentration slow component ground water discharge unpaved surface
Output	$S_{NH4-N,slow,t}$	[g N/s]	Ammonium load slow component ground water discharge unpaved surface
	$S_{NO3-N,slow,t}$	[g N/s]	Nitrate load slow component ground water discharge unpaved surface

Phosphor

In section 2.3.2 Reaction processes in the soil it is indicated that the adsorption/desorption of soil components is the most important process in the P management. Phosphor is fixed in the soil, because of which a steep phosphor profile comes into existence, which decreases along with increasing depth (Kroese et al, 1990). In The Netherlands the phosphor fixation capacity of the deeper soil layers is still hardly used. The phosphor runoff with deep ground water is, therefore, zero and in any case constant with the time.

$$S_{P-total,slow,t} = Q_{slow,t} * C_{P-total,slow,t} \qquad (23)$$

Input	$Q_{slow,t}$	[m³/s]	Slow component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{P-total,slow,t}$	[mg P/l]	Phosphor concentration slow component ground water discharge unpaved surface

Output	$S_{P-total,slow,t}$	[g P/s]	Phosphor load slow component ground water discharge unpaved surface

Target values

The concentrations of the slow component of ground water discharge are mainly determined by the type of soil and the land use. Sandy soil, clay soil and peaty soil are distinguished between. A further distinction is made by:

- Non-fertilised land;
- Fertilised grassland;
- Fertilised green maize farmland;
- Fertilised other farmland.

In addition, there are areas with a specific ground use, such as bulb-growing and greenhouse culture. The contribution by these areas to leaching of N and P is very specific due to the specific fertilisation and water management. In this case the user him/herself will have to estimate the parameters or derive these from measuring.

4.4.4.4 Conclusions

In the description of the water quality it was tried to picture the relation between the P and N loads discharged into the drainage system and the hydrograph. Zero order equations seem to be most suitable for a empirical approach in a simple model. In general, this approach is motivated by means of arguments regarding the processes. On-line measuring data of the N and P concentrations in the sub flows considered are hardly known. Model-related data are often applicable to longer periods (decades, seasons and years). A smaller step size in which also the relation is included with the discharge, requires a much more detailed insight into the processes than is available at this moment.

With regard to the target values of the concentration, the problem arises that the available data usually do not apply to the various ground water flows, on which this study is based. Therefore, the available data need to be translated for the subflows in this study. In addition, many data are not known. Also model-related values usually are not applicable directly to the subflows in this study. These values are often calculated in models, but only act as interim values that are not presented in reports. In order to generate values for the subflows, calculations could be executed, for example by means of ANIMO.

The smaller a step's size, the more the inaccuracy of the model results increases, because on this time scale the inaccuracy in the input parameters increases. This only applies to the description of the water quality.

4.5 Seepage

In addition to the discharges that are calculated for open water, paved surface and unpaved surface, the user may enter a term seepage, which is defined for the total surface.

$$q_{seep,t} = \frac{\Delta h}{c} \qquad (24\text{-a})$$

$$Q_{seep,t} = b\ A_{total}\ q_{seep,t} \qquad (24\text{-b})$$

Input	Δh	[m]	Hydraulic head difference
	c	[day]	Vertical hydraulic resistance

	A_{total}	[ha]	Total surface
Model Parameters	b^*	[-]	Conversion factor units
Output	$Q_{seep,t}$	[m³/s]	Discharge seepage

* The conversion factor is equal to 10000/(24*3600).

The related water quality is determined by a zero order equation.

$$S_{NH4-N,seep,t} = Q_{seep,t} * C_{NH4-N,seep,t} \qquad (25\text{-a})$$

$$S_{NO3-N,seep,t} = Q_{seept,t} * C_{NO3-N,seep,t} \qquad (25\text{-b})$$

Input	$Q_{seep,t}$	[m³/s]	Discharge seepage (formula 24)
Model Parameters	$C_{NH4-N,seep,t}$	[mg N/l]	Ammonium N-concentration discharge seepage
	$C_{NO3-N,seep,t}$	[mg N/l]	Nitrate concentration discharge seepage
Output	$S_{NH4-N,t}$	[g N/s]	Ammonium load discharge seepage
	$S_{NO3-N,t}$	[g N/s]	Nitrate load discharge seepage

$$S_{P-total,seep,t} = Q_{seep,t} * C_{P-total,seep,t} \qquad (26)$$

Input	$Q_{seep,t}$	[m³/s]	Discharge seepage
Model Parameters	$C_{P-total,seep,t}$	[mg P/l]	Phosphor concentration discharge seepage
Output	$S_{P-total,seep,t}$	[g P/s]	Phosphor load discharge seepage

Target values
The values for the seepage and the concentrations depend strongly on the local situation. It is therefore impossible to give target values. Mostly, local data are available about the seepage and the concentrations.

4.6 Total discharge and total load

$$Q_{unpaved,t} = Q_{sur,t} + Q_{quick,t} + Q_{slow,t} \qquad (27\text{-a})$$

$$Q_{total,t} = Q_{open\,water,t} + Q_{paved,t} + Q_{unpaved,t} + Q_{seep,t} \qquad (27\text{-b})$$

Input	$Q_{open\,water,t}$	[m³/s]	Discharge open water surface (formula 2-b)
	$Q_{unpaved,t}$	[m³/s]	Discharge unpaved surface (formula 27-a)
	$Q_{paved,t}$	[m³/s]	Discharge paved surface (formula 6-c)
	$Q_{sur,t}$	[m³/s]	Surface discharge unpaved surface (formula 15-b)
	$Q_{quick,t}$	[m³/s]	Quick component of ground water discharge unpaved surface (formula 16 or 17)

	$Q_{slow,t}$ $Q_{seep,t}$	[m³/s] [m³/s]	Slow component of ground water discharge unpaved surface (formula 16 or 17) Runoff seepage (formula 24)
Model Parameters	-	-	-
Output	$Q_{total,t}$	[m³/s]	Total discharge

The total of nitrate and ammonium loads in a catchment area is determined in accordance with:

$$S_{NH4-N,unpaved,t} = S_{NH4-N,sur,t} + S_{NH4-N,quick,t} + S_{NH4-N,slow,t} + S_{NH4-N,seep,t} \quad (28\text{-a})$$

$$S_{NO3-N,unpaved,t} = S_{NO3-N,sur,t} + S_{NO3-N,quick,t} + S_{NO3-N,slow,t} + S_{NO3-N,seep,t} \quad (28\text{-b})$$

$$S_{NH4-N,total,t} = S_{NH4-N,open\,water,t} + S_{NH4-N,paved,t} + S_{NH4-N,unpaved,t} \quad (28\text{-c})$$

$$S_{NO3-N,total,t} = S_{NO3-N,open\,water,t} + S_{NO3-N,paved,t} + S_{NO3-N,unpaved,t} \quad (28\text{-d})$$

$$S_{org-N,total,t} = S_{org-N,paved,t} + S_{org-N,sur,t} \quad (28\text{-e})$$

Input	$S_{NH4-N,open\,water,t}$	[g N/s]	Ammonium load open water surface (formula 3-a)
	$S_{NO3-N,open\,water,t}$	[g N/s]	Nitrate load open water surface (formula 3-b)
	$S_{NH4-N,unpaved,t}$	[g N/s]	Ammonium load unpaved surface (formula 28-a)
	$S_{NO3-N,unpaved,t}$	[g N/s]	Nitrate load unpaved surface (formula 28-b)
	$S_{NH4-N,paved,t}$	[g N/s]	Ammonium load paved surface (formula 7-a)
	$S_{NO3-N,paved,t}$	[g N/s]	Nitrate load paved surface (formula 7-b)
	$S_{NH4-N,sur,t}$	[g N/s]	Ammonium load surface runoff (formula 18-a)
	$S_{NO3-N,sur,t}$	[g N/s]	Nitrate load surface runoff (formula 18-b)
	$S_{NH4-N,quick,t}$	[g N/s]	Ammonium load quick component ground water discharge unpaved surface (formula 20-a)
	$S_{NO3-N,quick,t}$	[g N/s]	Nitrate load quick component ground water discharge unpaved surface (formula 20-b)
	$S_{NH4-N,slow,t}$	[g N/s]	Ammonium load slow component ground water discharge unpaved surface (formula 22-a)
	$S_{NO3-N,slow,t}$	[g N/s]	Nitrate load slow component ground water discharge unpaved surface (formula 22-b)
	$S_{NH4-N,seep,t}$	[g N/s]	Ammonium load wash out seepage(formula 25-a)
	$S_{NO3-N,seep,t}$	[g N/s]	Nitrate load wash out seepage(formula 25-b)
	$S_{org-N,paved,t}$	[g N/s]	Organically fixed nitrogen load paved surface (formula 7-c)
	$S_{org-N,sur,t}$	[g N/s]	Organically fixed nitrogen load surface runoff unpaved surface

			(formula 18-c)
Model Parameters	-	-	-
Output	$S_{NH4-N,total,t}$	[g N/s]	Total ammonium load
	$S_{NO3-N,total,t}$	[g N/s]	Total nitrate load
	$S_{org-N,total,t}$	[g N/s]	Total organically fixed nitrogen load

In the first version of the precipitation runoff module the term organically fixed nitrogen has not been included.

The total phosphor load is determined in accordance with:

$$S_{P-total,unpaved,t} = S_{P-total,sur,t} + S_{P-total,quick,t} + S_{P-total,slow,t} + S_{P-total,seep,t} \quad (29\text{-A})$$

$$S_{P-total,total,t} = S_{P-total,openwater,t} + S_{P-total,paved,t} + S_{P-total,unpaved,t} \quad (29\text{-B})$$

Input	$S_{P-total,openwater,t}$	[g P/s]	Phosphor load open water surface (formula 4)
	$S_{P-total,unpaved,t}$	[g P/s]	Phosphor load unpaved surface (formula 29-a)
	$S_{P-total,paved,t}$	[g P/s]	Phosphor load paved surface (formula 8)
	$S_{P-total,sur,t}$	[g P/s]	Phosphor load surface runoff (formula 19)
	$S_{P-total,quick,t}$	[g P/s]	Phosphor load quick component ground water discharge unpaved surface (formula 21)
	$S_{P-total,slow,t}$	[g P/s]	Phosphor load slow component ground water discharge unpaved surface (formula 23)
	$S_{P-total,seep,t}$	[g P/s]	Phosphor load discharge seepage (formula 26)
Model Parameters	-	-	-
Output	$S_{P-total,total,t}$	[g P/s]	Total phosphor load

4.7 Relation ground water discharge and surface water level

The ground water discharges into the drainage system. The discharge therefore depends on the surface water level. This relation can only be included when the surface water level is input from the flow model. This is contrary to the point of departure of a stand alone precipitation runoff module.

Two options are mentioned in order to include this relation without skipping the point of departure of a stand alone precipitation runoff module:

1. simplified calculation of the surface water level

The surface water level is calculated in the precipitation runoff module by a water balance for the drainage system. The inflow is the calculated ground water discharge, the outflow is the drainage as calculated in a simplified manner. Disadvantage of this option is the separated calculation of the surface water level from the flow model. Because of the simplified calculation in the precipitation runoff module, the calculated surface water level will deviate from the calculated one in the flow model.

2. surface water level as input

In this option the surface water level is input in the precipitation runoff module. This time series can be obtained from a flow model. By an iterative process, the relation ground water discharge and surface water level can be approached.

The ground water discharge is described by a configuration of linear reservoirs (see section 2.3.4.3). The relation between the ground water discharge and surface water level is implicitly discounted in the time constant of the reservoirs, whereas a constant surface water level is assumed. The relation between the ground water discharge and surface water level becomes relevant in case of more fluctuating surface water levels.

The fluctuations in surface water levels will be relatively small compared to the fluctuations of the ground water level for sloping areas. Assuming a constant surface water level will be sufficient. However, in specific situation strong fluctuations can occur. For example with large percentages of paved area, so the precipitation will be stored rather quickly in the surface water. Also within downstream polder areas, large decreases of the surface water level can occur.

5. Evaluation

With the precipitation runoff module, a model is developed to simulate the discharge processes, both the hydrographs, leaching and runoff of nutrients.

The point of departure of the precipitation runoff module were a simple set-up for operational use, connection with widely used precipitation runoff models, and creating a direct joining of a precipitation runoff module and a flow model. The technical design fits to all point of departure. The simple set-up of the technical design create a widely usable application. Using the soil moisture reservoir and linear reservoirs, the set-up connects to widely used precipitation runoff models. By joining the STOWA/Unie stekkerdoos WATER, a direct joint is made between precipitation runoff module and a flow model.

The set-up chosen is indeed simple but it is also extensive. The user will have to enter a vast amount of parameters before using the module. That this relatively extensive form was chosen anyway is caused by two aspects. On the one hand, the wish existed to make the model suitable for an extensive application area (with regard to type and application). On the other hand, the wish existed to describe both the water quantity and the water quality.

In the precipitation runoff module, pragmatic solutions were often chosen. At some points, the processes are not described (capillary rise, feedback with the surface water level). Depending on the wishes of the users, extensions may be added in a later stage.

5.1 Hydrograph description

The Precipitation Runoff Module developed is of a strongly empirical nature. As a result, the parameters in the model usually do not have a direct physical meaning. Therefore, target values for the model parameters have been included in this manual. In view of the complexity of the processes in catchment areas (local variation in type of soil, slope, ground use, etc.), also the target values indicated will cause deviations in the results. ***It is strongly recommended to calibrate the model parameters based on measured discharges.***

5.2 Description water quality

In the theory it was concluded that the processes of leaching and runoff of nutrients are extremely complex. The value of a simple concept for the description of the water quality will therefore be restricted. Since an estimate based on fist rules and target values obtained from literature will give a best guess, this concept will be helpfull for water boards. Also due to the complexity of the processes of micro pollutants, a description of these solutes was excluded from RAM. RAM is therefore restricted to the leaching and runoff of nutrients only.

Point of departure for the description of the water quality is a direct link with the hygrograph. Concentrations are attributed to the subflows, which are affected by the supply, the reaction processes and the discharge. These concentrations are worked out for nitrogen, phosphor and ammonium. The experience with this concept can be used to decide whether a more detailed concept is necessary or not.

Similar to the hydrograph description, it is strongly recommended to calibrate the model parameters.

5.3 Recommendations

After delivery of the first version of the precipitation runoff module, experience will be acquired in using the module. Based on these experiences and supplementary wishes, the precipitation runoff module may be extended in a later stage.

Aspects that were addressed during the development process of the precipitation runoff module, may increase the applicability of the precipitation runoff module. Some relevant points of improvement are described below.

Ground water discharge reduction in case of high surface water levels
In case of high surface water levels, the ground water runoff may stagnate. In the current version of the precipitation runoff module the user him/herself needs to determine when reduction occurs. The applicability of the precipitation runoff module will increase, if the ground water runoff is dependent from the surface water level (see section 3.7).

Refinement soil moisture reservoir
In the current version of the precipitation runoff module linear relations may be entered for the evapotranspiration relation (formula 12) and the percolation relation (formula 13). The applicability of the soil moisture reservoir is increased, if the user her/himself is able to define a (non-linear) relation. Furthermore, the soil moisture reservoir may be improved by including a capillary rise relation and by adding a retardation term.

Determination maximum percolation and distribution code
In the soil moisture reservoir the maximum percolation is entered by the user (formula 13-c). Hardly any guidelines for these values are known in the literature. In a more extensive version, the determination of the maximum percolation may be worked out in further detail. This also applies to the distribution code for the slow and quick ground water runoff (formulas 16 and 17).

Water quality description
The usability of the water quality description in the precipitation runoff module will have to be monitored critically. It is recommended that the model is tested during a prolonged period of time in which the model results are compared to the measuring values (calibration). From an evaluation of these experiences, it will appear whether the differentiation within the subflows is sufficient, or that a further differentiation is deemed useful. Based on this evaluation the model may be adapted.

6. References

6.1 General

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6.2 Precipitation-runoff relation

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7. Index

Appendix A Evapotranspiration

Instead of the evaporation from a hypothetical water surface, also the evapotranspiration of a reference crop (according to Makkink) may be taken as measure for the potential crop evapotranspiration.

$$E_p = f\ E_r$$

In which

E_r : reference crop evapotranspiration Makkink [mm/day]
f : crop factor Makkink for the crop involved [-]
E_o : open water evaporation Penmann [mm/day]

The reference evapotranspiration may be calculated through:

$$\lambda E_r = 0.65 \frac{S}{S + \gamma} K \downarrow$$

In which

$K\downarrow$: Global radiation [W/m^2]
λ : Specific evaporation heat of the water [J/kg]
γ : Psychrometric constant [mbar/K]
Δ : Slope of the saturation water vapour temperature curve at air temperature [mbar/K]

Combination of the Penmann formula and the Makkink formula results in:

$$f = \frac{E_o}{E_r} g$$

In which

g : crop factor Penmann

The crop factor according to Makkink (Cultuurtechnisch Vademecum, 1988)

month	April			May			June			July			August			September		
decade	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
grass	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9
cereals	0.7	0.8	0.9	1.0	1.0	1.0	1.2	1.2	1.2	1.0	0.9	0.8	0.6	-	-	-	-	-
maize	-	-	-	0.5	0.7	0.8	0.9	1.0	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
potatoes	-	-	-	-	0.7	0.9	1.0	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	0.7	-	-
sugar beets	-	-	-	0.5	0.5	0.5	0.8	1.0	1.0	1.2	1.1	1.1	1.1	1.2	1.2	1.2	1.1	1.1
leguminous plants	-	0.5	0.7	0.8	0.9	1.0	1.2	1.2	1.2	1.0	0.8	-	-	-	-	-	-	-
Plant unions	0.5	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-
sowing unions	-	0.4	0.5	0.5	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.7	-	-
chicory	-	-	-	-	-	-	0.5	0.5	0.5	0.8	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
winter carrots	-	-	-	-	-	-	0.5	0.5	0.5	0.8	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
celery	-	-			-	0.5	0.7	0.7	0.7	0.8	0.9	1.0	1.1	1.1	1.1	1.1	1.1	-
leeks	-	-	-	-	0.5	0.5	0.5	0.5	0.7	0.7	0.8	0.8	0.8	1.0	0.9	0.9	0.9	0.9
bulb/tube crops	-	-	-	-	0.5	0.7	0.7	0.9	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
pome/stone fruit (fully grown)	1.0	1.0	1.0	1.4	1.4	1.4	1.6	1.6	1.6	1.7	1.7	1.7	1.3	1.3	1.2	1.2	1.2	1.2

Appendix B Staring series

Tabel 3.2.3. Indeling naar textuur (in % van de minerale delen), organische-stofgehalte (in % van de grond) en mediaan van de zandfractie (M50) van bouwstenen uit de Staringreeks volgens de textuur-terminologie van het systeem van bodemclassificatie voor Nederland (*Wösten e.a.*, 1987).

Bouwsteen	Leem (%)	Lutum (%)	Organische stof (%)	M50 µm
BOVENGRONDEN				
Zand				
B1 leemarm, zeer fijn tot matig fijn zand	0 - 10		0 - 15	105 - 210
B2 zwak lemig, zeer fijn tot matig fijn zand	10 - 18		0 - 15	105 - 210
B3 sterk lemig, zeer fijn tot matig fijn zand	18 - 33		0 - 15	105 - 210
B4 zeer sterk lemig, zeer fijn tot matig fijn zand	33 - 50		0 - 15	105 - 210
B5* grof zand			0 - 15	210 - 2000
B6* keileem	0 - 50		0 - 15	50 - 2000
Zavel				
B7 zeer lichte zavel		8 - 12	0 - 15	
B8 matig lichte zavel		12 - 18	0 - 15	
B9* zware zavel		18 - 25	0 - 15	
Klei				
B10 lichte klei		25 - 35	0 - 15	
B11 matig zware klei		35 - 50	0 - 15	
B12 zeer zware klei		50 - 100	0 - 15	
Leem				
B13* zandige leem	50 - 85		0 - 15	
B14* siltige leem	85 - 100		0 - 15	
Moerig				
B15* venig zand		0 - 8	15 - 25	
B16 zandig veen en veen		0 - 8	23 - 100	
B17* venige klei		8 - 100	16 - 45	
B18 kleiig veen		8 - 100	25 - 70	
ONDERGRONDEN				
Zand				
O1 leemarm, zeer fijn tot matig fijn zand	0 - 10		0 - 3	105 - 210
O2 zwak lemig, zeer fijn tot matig fijn zand	10 - 18		0 - 3	105 - 210
O3 sterk lemig, zeer fijn tot matig fijn zand	18 - 33		0 - 3	105 - 210
O4 zeer sterk lemig, zeer fijn tot matig fijn zand	33 - 50		0 - 3	105 - 210
O5 grof zand			0 - 3	210 - 2000
O6 keileem	0 - 50		0 - 3	50 - 2000
O7* beekleem	33 - 50			
Zavel				
O8 zeer licht zavel	8 - 12		0 - 3	
O9 matig lichte zavel	12 - 18		0 - 3	
O10 zware zavel	18 - 25		0 - 3	
Klei				
O11 lichte klei	25 - 35		0 - 3	
O12 matig zware klei	35 - 50		0 - 3	
O13 zeer zware klei	50 - 100		0 - 3	
Leem				
O14* zandige leem	50 - 85		0 - 3	
O15 siltige leem	85 - 100		0 - 3	
Veen				
O16 oligotroof veen			35 - 100	
O17 mesotroof en eutroof veen			35 - 100	
O18* moerige tussenlaag			15 - 35	

* Aan deze bouwsteen zijn tot op heden onvoldoende metingen verricht om een gemiddelde relatie te kunnen presenteren.

Tabel 3.2.4. Volumefractie water θ (%) in relatie tot de drukhoogte h (cm resp. pF) en de hoeveelheid beschikbaar hangwater (θ_{hw}) bij 3 waarden van de veldcapaciteit voor bovengronden en ondergronden van de Staringreeks (*Wösten e.a.*, 1987).

	θ (%) bij 13 waarden voor |h|, resp. pF													θ_{hw} bij pF		
														1,7	2,0	2,3
|h| (cm)	1	10	20	31	50	100	250	500	1000	2500	5000	10000	16000	-	-	-
pF	0,0	1,0	1,3	1,5	1,7	2,0	2,4	2,7	3,0	3,4	3,7	4,0	4,2	4,2	4,2	4,2
BOVENGRONDEN																
B1	37,1	36,3	35,7	34,7	28,0	20,1	12,0	9,8	7,4	5,4	4,3	3,4	3,0	25,0	17,1	11,5
B2	43,2	40,1	39,7	38,1	35,1	27,6	20,3	15,5	11,8	8,7	6,7	5,3	4,5	30,6	23,1	17,5
B3	44,9	42,8	41,6	40,6	39,1	34,2	24,9	19,3	15,2	11,5	9,3	7,6	6,7	32,4	27,5	20,3
B4	[illegible]	39,8	38,2	37,0	34,7	28,8	18,7	12,8	9,6	7,0	5,7	4,7	4,1	30,6	24,7	17,0
B7	40,7	38,0	37,3	36,6	35,6	32,4	25,4	21,7	19,0	16,0	14,0	12,1	11,0	24,6	21,4	15,9
B8	40,1	37,7	36,9	36,2	35,2	32,8	27,4	23,3	19,6	15,9	13,2	[illegible]	9,9	25,3	22,9	18,8
B10	44,8	40,8	40,1	39,6	38,9	37,7	35,1	31,9	26,3	21,6	18,7	15,8	14,3	24,5	23,4	21,6
B11	51,7	47,2	46,3	45,9	45,2	43,6	39,4	34,4	29,7	24,8	21,7	18,8	17,0	28,2	26,6	23,7
B12	57,8	53,3	52,4	51,7	50,9	49,5	46,4	43,5	40,5	36,2	33,1	30,1	28,1	22,8	21,4	19,2
B16	73,3	67,7	65,8	64,4	62,7	58,9	50,5	40,9	30,3	22.	17,6	14,5	12,9	49,8	46,0	40,1
B18	71,7	69,8	68,5	67,1	65,7	60,9	53,9	48,6	44,0	38,6	34,6	30,6	27,9	37,3	33,0	27,7
ONDERGRONDEN																
O1	35,4	31,6	30,3	28,6	24,2	12,1	5,6	3,7	2,7	2,0	1,6	1,3	1,1	23,1	11,0	5,7
O2	38,1	35,4	34,0	32,7	30,4	19,7	9,9	7,3	5,7	4,6	3,9	3,3	2,9	27,5	16,8	9,0
O3	34,7	32,1	30,8	29,5	27,2	19,4	[illegible]	7,5	5,5	4,1	3,2	2,6	2,3	24,9	17,1	10,7
O4	35,8	34,0	32,9	31,4	29,7	23,2	14,2	9,2	6,2	4,4	3,4	2,8	2,5	26,7	20,7	11,8
O5	33,2	30,3	25,4	19,1	11,4	7,6	4,6	3,5	2,7	2,0	1,6	1,2	1,0	10,4	6,6	4,2
O6	41,2	38,7	37,5	36,4	35,5	33,7	30,3	27,6	25,3	22,2	19,8	17,5	16,4	19,1	17,3	14,8
O8	42,3	38,9	38,3	37,8	37,1	32,6	21,1	17,5	14,9	12,4	10,7	9,3	8,4	28,7	24,2	14,6
O9	41,4	38,2	37,2	36,4	35,3	31,8	22,8	18,7	15,4	12,4	10,6	9,1	8,1	27,2	23,7	16,5
O10	43,9	42,5	41,7	40,9	40,0	38,1	32,0	26,7	20,9	16,6	[illegible]	11,8	10,4	29,6	27,7	23,3
O11	41,9	40,0	39,3	38,7	38,1	36,5	33,1	29,6	26,2	[illegible]	19,2	16,6	15,0	23,1	21,5	[illegible]
O12	49,2	47,8	47,3	47,0	46,1	45,2	41,1	36,7	31,3	26,2	23,1	20,2	18,4	28,0	26,8	24,0
O13	58,0	54,9	54,4	54,0	53,5	52,7	49,9	47,2	43,4	39,0	35,9	32,7	30,2	23,3	22,0	20,4
O15	43,7	40,9	40,3	39,6	38,6	36,9	31,6	25,7	20,7	17,1	12,7	10,2	8,5	30,3	28,4	24,7
O16	87,8	81,9	80,3	78,9	75,5	70,9	56,9	45,0	37,8	29,6	24,4	21,1	18,5	57,0	52,4	42,4
O17	89,3	84,6	83,3	82,2	80,6	76,3	65,0	54,2	43,6	34,4	28,6	23,7	20,9	59,7	55,4	47,2

Appendix C Translation definitions

Dutch	English
hydrologische kringloop	**hydrological cycle**
afvoer	discharge
afvoerbare neerslag	effective precipitation
afwateringsstelsel	drainage system
bergingscapaciteit van de onverzadigde zone	storage capacity of the unsaturated zone
capillaire opstijging	Upward capillary migration /capillary rise
capillaire zoom	capillary fringe
depressieberging	Storage in surface depressions
drain	drain pipe
drainage-afvoer	drainage
evaporatie	evaporation
evapotranspiratie	evapotranspiration
grondafvoer	ground water discharge
grondwaterstand	ground water level
grondwaterstandsdiepte	depth of the groundwater level
hydrologische kringloop	hydrologic cycle
infiltratie	infiltration
infiltratiecapaciteit	infiltration capacity
interceptie	interception
kwel	seepage / exfiltration
neerslag	precipitation
neerslagintensiteit	precipitation intensity
neerslagoverschot	precipitation
netto neerslag	precipitation excess
onverzadigde zone	unsaturated zone
ontwatering	drainage
oppervlakte-afvoer	surface runoff
percolatie	percolation
schijnspiegel	perched water table / apparent water table
schijnspiegelafvoer	interflow

specifieke afvoer	specific discharge
stroomgebied	catchment area
transpiratie	transpiration
veldcapaciteit	field capacity
verwelkingspunt	wilting point
verzadigde zone	zone of saturation
waterbalans	water balance
wegzijging	downward seepage
wortelzone	root zone

waterkwaliteit	**water quality**
adsorptie	adsorption
afspoeling	runoff
denitrificatie	denitrification
desorptie	desorption
droge depositie	dry deposition
fosforbindend vermogen (FVB)	phosphorus fixation capacity
immobilisatie	fixation / immobilization
mineralisatie	mineralization
natte depositie	wet deposition
nitrificatie	nitrification
omzettingsprocessen	reaction processes
uitspoeling	leaching
vervluchting	volatilization

Appendix D Definition of terms

Often various terms with the same meaning are in circulation. It is important to the readability to univocally define the terms used. The definitions of the terms regarding the hydrological cycle are kept in accordance with the definitions listed in the hydrologic glossary (CHO-TNO, 1988), whenever possible. Only in a few cases this rule was deviated from. The terms used in the description of the water quality is kept to the definitions generally accepted in the literature, whenever possible.

Capillary fringe	The part of the saturated zone located directly above the phreatic surface.
Capillary rise	Upward flow of water above the phreatic surface.
Catchment area	An area from which the outgoing water is discharged by one specific water-course.
Depth of the ground water level	The height compared to a reference level of a point where the ground water has a pressure height that equals zero.
Discharge	Instantanious discharge into a canal at a given point in time, in volume per time interval.
Downward seepage	Downward flow of groundwater
Drainage	The discharge of water from plots across and through the ground and in some events through drain pipes and gullies to a system of larger watercourses
Drainage	Flowing off of ground water through drain pipes.
Drain pipe	Underground drainage pipes with a pervious or perforated wall, which serves to discharge ground water.
Effective precipitation	Part of the precipitation that is discharged from the surface or subsoil into the surface water.
Evaporation	Evaporation from open water, interception and ground
Evapotranspiration	The total of evaporation and transpiration
Field capacity	The water content that is found in the toplayer of the soil, a few days after a wet period. This is not constant as the absorption pressure varies depending on the depth of the ground water level.
Ground water level depth	The distance between the ground surface and the ground water level.
Hydrologic cycle	A continuous process in which water circulates from the oceans through the atmosphere and the rivers back to the oceans.

Infiltration — The phenomenon that water enters into the ground at the ground surface.

Infiltration capacity — Maximum infiltration intensity, which is possible at the given circumstances (among other things dependent of the water content of the soil).

Interception — Part of the gross precipitation that is intercepted by the vegetation or other structures and that subsequently evaporates.

Interflow — Horizontal transportation of ground water in a shallow saturated layer. The term is preferably used if this phenomenon is of a temporary nature; this phenomenon is usually accommodated by a perched water table.

Perched water table — Phreatic surface of a ground water body located on a semi unpaved layer, under which another unsaturated zone exists.

Percolation — Downward movement of water in the unsaturated zone.

Precipitation — The average specific precipitation intensity (the precipitation falling per unit of horizontal surface) above the surface; in other words: the actually measured precipitation in the area.

Precipitation excess — The difference between the gross precipitation and the interception.

Precipitation intensity — The actually fallen precipitation per unit of time.

Precipitation surplus — The difference between the excess precipitation and the potential evapotranspiration.

Root zone — The soil layer in which the living roots are present, usually considered as the layer in which the main part of the roots are present.

Saturated zone — Part of the soil in which the pores are completely filled with water, including the capillary fringe.

Seepage — Seeping through of ground water under the influence of higher hydraulic head outside the area under consideration; seeping through of water, which is supplied on the surface within the area, is outside the scope of this term. Seeping through may, among other things, occur directly on the ground surface, in ditches, drains or through capillary rise.

Specific discharge — Discharge intensity in a watercourse during a time interval, in volume per time interval per surface.

Storage capacity of the unsaturated zone — The amount of water that can be stored in the unsaturated zone until field capacity is reached.

Storage in surface depressions — Storage of precipitation in hollows on the surface level, appearing when the precipitation intensity surpasses the infiltration intensity.

Surface runoff — Runoff of precipitation occurring over the ground surface (including paved surfaces such as roads, roofs, airports, etc.)

Transpiration — The evaporation flux through the stomas and cuticulas of a dry surface of plants.

Unsaturated zone — Part of the ground above the phreatic surface, in which the pores contain both water and air.

Water balance — The comparison of the amounts of water involved in supply, discharge, withdrawal and change in storage within a given area during a specific period of time.

Wilting point — The water content of the soil at which it is no longer possible for the plant to absorb the ground water by means of the roots.

5. Evaluation

Terms i[illegible]

Adsorption — Fixation of substances to soil particles

Denitrification — Reaction process during which nitrate is converted into N_2 by denitrifying bacteria (anoxic and heterotrophic circumstances).

Desorption — Being released of substances which are bound to soil particles

Dry deposition — Supply of substances through dust participle from the air falling onto the ground.

Immobilisation — Fixing substances so that these are not available for washing out or running off.

Mineralisation — Reaction processes during which substances in the soil are converted into other substances by oxidation.

Nitrification — Conversion process during which ammonium is converted into nitrate by nitrificating bacteria (aerobic and autotrophic circumstances).

Phosphor fixation capacity — Degree in which a soil type is able to fix phosphor to soil particles

Reaction processes — Reaction processes in the soil during which substances are converted.

Runoff — Discharge of substances through surface water runoff

Volatiltzation — The transformation of a substance from a liquid form to the gas phase.

Washing out — Discharge of substances through ground water runoff

Wet deposition — Supply of substances through precipitation falling onto the ground.

5.1 Hydrograph description

The Precipitation Runoff Module developed is of a strongly empirical nature. As a result, the parameters in the model usually do not have a direct physical [illegible]. Therefore [illegible] values for the model parameters have been included [illegible]. In view of the complexity of the processes in catchment areas [illegible] ground use, etc.), also the target values [illegible] in the results. ***It is strongly recommended to calibrate the model parameters based on measured discharges.***

5.2 Description water quality

[illegible] that the processes of leaching and runoff of [illegible] are extremely complex. The value of a simple concept for the [illegible] of the water quality will therefore be restricted. Since an estimate [illegible] obtained from literature will give a best [illegible] helpfull for water boards. Also due to the complexity [illegible] description of these solutes was excluded [illegible] the leaching and runoff of nutrient [illegible].

Appendix E Overview symboles

a	[-]	Conversion factor units (= 10/[24*3600])
b	[-]	Conversion factor units (= 1000/[24*3600])
$A_{open\ water}$	[ha]	Open water surface
A_{paved}	[ha]	Paved surface
$A_{unpaved}$	[ha]	Unpaved surface
A_{sewer}	[ha]	Separated sewer system surface
A_{total}	[ha]	Total surface (where seepage occurs)
B_{max}	[mm]	Maximum storage in ground depressions
B_t	[mm]	Storage in ground depressions
E_a	[mm/day]	Actual evapotranspiration
E_o	[mm/day]	Open water evaporation Panmann
E_r	[mm/day]	Reference crop evaporation Makkink
f	[-]	Crop factor Makkink
f_o	[-]	Crop factor Makkink for open water
I_{max}	[mm/day]	Infiltration capacity
I_t	[mm/day]	Infiltration intensity
k[illegible]	[day]	Time constant reservoir open water surface
k[illegible]	[day]	Time constant reservoir slow ground water drainage
k_r	[day]	Time constant reservoir separated sewage system surface
k_s	[day]	Time constant reservoir quick ground water drainage
k_{sur}	[day]	Time constant reservoir surface drainage unpaved surface
k_v	[day]	Time constant reservoir paved surface
d	[-]	Number of reservoirs quick ground water drainage for the Kraayenhoff and de Leur models
m	[-]	Number of reservoirs quick ground water drainage for the Nash-cascades model
n	[-]	Number of reservoirs slow ground water drainage
N	[-]	Denitrification factor
P_b	[mm/day]	Precipitation intensity
$P_{N,open\ water}$	[mm/day]	Effective precipitation open water surface
$P_{N\ paved}$	[mm/day]	Effective precipitation paved surface
P_{perc}	[mm/day]	Effective precipitation unpaved surface
$P_{per,\ max}$	[mm/day]	Percolation occurring between pF = 0 and pF = 2 (maximum)
$P_{N\ sur}$	[mm/day]	Effective precipitation surface drainage
$q_{open\ water}$	[mm/day]	Specific runoff open water surface

q_{paved}	[mm/day]	Specific runoff paved surface
q_{quick}	[mm/day]	Specific runoff quick ground water runoff unpaved surface
q_{seep}	[mm/day]	Specific runoff seepage
q_{sewer}	[mm/day]	Specific runoff separated sewer system surface
q_{slow}	[mm/day]	Specific runoff slow ground water drainage unpaved surface
q_{sur}	[mm/day]	Specific runoff surface drainage unpaved surface
$q_{unpaved}$	[mm/day]	Specific runoff unpaved surface
$Q_{open\ water}$	[m³/s]	Discharge open water surface
Q_{paved}	[m³/s]	Discharge paved surface
Q_{quick}	[m³/s]	Quick ground water drainage unpaved surface
Q_{seep}	[m³/s]	Seepage
Q_{slow}	[m³/s]	Slow ground water drainage unpaved surface
Q_{sur}	[m³/s]	Surface drainage unpaved surface
$Q_{unpaved}$	[m³/s]	Discharge unpaved surface
Q_{total}	[m³/s]	Total drainage
β	[-]	Distribution key for quick and slow ground water drainage
Δt	[day]	Time step
Φ	[mm]	Actual moisture storage
$\Phi_{pF=0}$	[mm]	Moisture storage at pF = 0 (saturated)
$\Phi_{pF=2}$	[mm]	Moisture storage at pF = 2 (field capacity)
$\Phi_{pF=4.2}$	[mm]	Moisture storage at pF = 4.2 (wilting point)
Δh	[m]	Hydraulic head diffecrence
c	[day]	Vertical hydraulic resistance
$C_{NH4-N,\ paved}$	[mg N/l]	Ammonium-N concentration paved surface
$C_{NH4-N,\ precipitation}$	[mg N/l]	Ammonium-N concentration precipitation
$C_{NH4-N,\ seepage}$	[mg N/l]	Ammonium-N concentration seepage
$C_{NH4-N,\ slow}$	[mg N/l]	Ammonium-N concentration slow ground water runoff unpaved surface
$C_{NH4-N,\ sur}$	[mg N/l]	Ammonium-N concentration surface runoff unpaved surface
$C_{NH4-N,\ quick}$	[mg N/l]	Ammonium-N concentration quick ground water runoff unpaved surface
$C_{NH4-N,\ unpaved}$	[mg N/l]	Ammonium-N concentration unpaved surface
$C_{NO3-N,\ paved}$	[mg N/l]	Nitrate-N concentration paved surface
$C_{NO3-N,\ precipitation}$	[mg N/l]	Nitrate-N concentration precipitation
$C_{NO3-N,\ seepage}$	[mg N/l]	Nitrate-N concentration seepage
$C_{NO3-N,\ slow}$	[mg N/l]	Nitrate-N concentration slow ground water runoff unpaved surface
$C_{NO3-N,\ sur}$	[mg N/l]	Nitrate-N concentration surface runoff unpaved surface
$C_{NO3-N,\ quick}$	[mg N/l]	Nitrate-N concentration quick ground water runoff unpaved surface
$C_{NO3-N,\ unpaved}$	[mg N/l]	Nitrate-N concentration unpaved surface
$C_{org-N,\ paved}$	[mg N/l]	Organically fixed nitrogen concentration paved surface
$C_{org-N,\ sur}$	[mg N/l]	Organically fixed nitrogen concentration surface drainage unpaved surface
$C_{P\ total,\ paved}$	[mg P/l]	Phospor concentration paved surface
$C_{P\ total,\ precipitation}$	[mg P/l]	Phospor concentration precipitation
$C_{P\ total,\ quick}$	[mg P/l]	Phospor concentration quick ground water runoff unpaved surface
$C_{P\ total,\ seepage}$	[mg P/l]	Phospor concentration seepage
$C_{P\ total,\ slow}$	[mg P/l]	Phospor concentration slow ground water runoff unpaved surface
$C_{P\ total,\ sur}$	[mg P/l]	Phospor concentration surface runoff unpaved surface
$C_{P\ total,\ unpaved}$	[mg P/l]	Phospor concentration unpaved surface
$S_{NH4-N,\ open\ water}$	[kg N/s]	Ammonium-N load open water surface
$S_{NH4-N,\ paved}$	[kg N/s]	Ammonium-N load paved surface
$S_{NH4-N,\ quick}$	[kg N/s]	Ammonium-N load quick ground water runoff unpaved surface

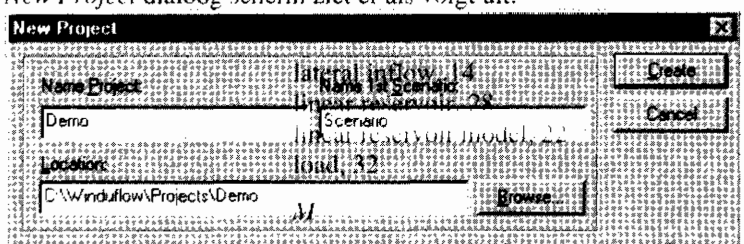
$S_{NH4\text{-}N,\ seepage}$	[kg N/s]	Ammonium-N load seepage/percolation
$S_{NH4\text{-}N,\ slow}$	[kg N/s]	Ammonium-N load slow ground water runoff unpaved surface
$S_{NH4\text{-}N,\ sur}$	[kg N/s]	Ammonium-N load surface runoff unpaved surface
$S_{NH4\text{-}N,\ total}$	[kg N/s]	Total ammonium-N load
$S_{NH4\text{-}N,\ unpaved}$	[kg N/s]	Ammonium-N load unpaved surface
$S_{NO3\text{-}N,\ open\ water}$	[kg N/s]	Nitrate load open water surface
$S_{NO3\text{-}N,\ paved}$	[kg N/s]	Nitrate load paved surface
$S_{NO3\text{-}N,\ seepage}$	[kg N/s]	Nitrate load seepage/percolation
$S_{NO3\text{-}N,\ quick}$	[kg N/s]	Nitrate load quick ground water runoff unpaved surface
$S_{NO3\text{-}N,\ slow}$	[kg N/s]	Nitrate load slow ground water runoff unpaved surface
$S_{NO3\text{-}N,\ sur}$	[kg N/s]	Nitrate load surface runoff unpaved surface
$S_{NO3\text{-}N,\ total}$	[kg N/s]	Total nitrate load
$S_{NO3\text{-}N,\ unpaved}$	[kg N/s]	Nitrate load unpaved surface
$S_{org\text{-}N,\ paved}$	[kg N/s]	Organically fixed nitrogen concentration paved surface
$S_{org\text{-}N,\ sur}$	[kg N/s]	Organically fixed nitrogen concentration surface drainage unpaved surface
$S_{P\ total\ N,\ open\ water}$	[kg P/s]	Phosphor load open water surface
$S_{P\ total\ N,\ paved}$	[kg P/s]	Phosphor load paved surface
$S_{P\ total\ N,\ quick}$	[kg P/s]	Phosphor load seepage
$S_{P\ total\text{-}N,\ seepage}$	[kg P/s]	Phosphor load quick ground water runoff unpaved surface
$S_{P\text{-}total\text{-}N,\ slow}$	[kg P/s]	Phosphor load slow ground water runoff unpaved surface
$S_{P\ total\text{-}N,\ sur}$	[kg P/s]	Phosphor load surface runoff unpaved surface
$S_{P\ total\text{-}N,\ total}$	[kg P/s]	Total phosphor load
$S_{P\text{-}total\text{-}N,\ unpaved}$	[kg P/s]	Phosphor load unpaved surface

2. Aan de slag met DMS

In dit hoofdstuk wordt stap voor stap een simpel voorbeeld doorlopen. Dit hoofdstuk is bedoeld voor de beginnende gebruiker die bekend wil raken met het invoeren van de gegevens, het uitvoeren van een berekening en het bekijken van de resultaten met behulp van DMS. Voordat er gestart kan worden met de eerste stappen van dit voorbeeld, moet allereerst het programma correct geïnstalleerd zijn.

2.1. Definieer een Project

Na het starten van het programma Duflow Modelling Studio (DMS), kan je een Project definiëren door het *New* commando uit het *File* menu te selecteren. Het *New Project* dialoog scherm ziet er als volgt uit:



Kies een naam voor het Project, bijvoorbeeld **Demo**. Een sub-directory wordt automatisch aangemaakt door DMS, de locatie van deze sub-directory kan worden aangepast door een ander pad in te typen in het *Location* veld. Door op *Create* te drukken wordt een nieuw project gecreëerd.

DMS heeft nu het scherm geopend, dat we de *Scenario Manager* noemen. De Scenario Manager toont alle huidig geopende projecten, met bijbehorende Scenario's, in een boom structuur. Elk Scenario bevat een verzameling van gegevens, die zichtbaar worden of verdwijnen door het aanklikken van de plus of minus in de boom.

= Zichtbaar maken van Scenario Manager

Als de Scenario Manager Window niet zichtbaar is, kan het te voorschijn worden gehaald door middel van de *Scenario Manager* optie uit het *View* menu.

De Scenario Manager zorgt ervoor dat er, binnen hetzelfde Project, met verschillende verzamelingen van gegevens gewerkt kan worden. Het is bijvoorbeeld mogelijk om een simulatie van twee Scenario's uit te voeren met identieke invoer gegevens, met uitzondering van de neerslag. Dit geeft de gebruiker de mogelijkheid om makkelijk resultaten van een zware regenbui te evalueren. De Scenario kan zelf de invoer gegevens bevatten of het kan verwijzen naar de invoer gegevens van een ander Scenario. Elke Scenario registreert een verzameling van gegevens. Per verzameling kan de gebruiker beslissen om de gegevens in de eigen Scenario directory te bewaren of om de gegevens van een ander Scenario te verkrijgen.

= Bewerk Omschrijving

Door de optie *Description* te kiezen uit het *Scenario* menu kan een uitgebreide omschrijving van het Scenario worden opgeslagen.

2.2. Ontwerp het netwerk

= Open Netwerk window

Door het *Open Network window* commando uit het *View* menu te gebruiken, wordt het Netwerk Window geopend. Hier kan de schematisatie van het netwerk ontworpen en/of interactief aangepast worden.

NB Als een gewenst icon niet zichtbaar is op één van de werkbalken, kies *Customize...* uit het *Options* menu. DMS laat het Customize dialoog scherm zien.

Op het **Command** tab blad worden de, bij de geselecteerde categorie horende, knoppen getoond. De knop wordt toegevoegd aan de werkbalk door deze te slepen vanuit het Customize dialoog scherm naar de gewenste werkbalk. Door het van de werkbalk af te trekken wordt de knop van de werkbalk verwijderd.

Het Netwerk kan opgebouwd worden op een geografische achtergrond door de optie *Use geographic map as background* in het Project Properties dialoog scherm aan te zetten. Dit dialoog scherm wordt zichtbaar door het Properties commando te selecteren uit het Project menu.

= Toon Kaartlagen

Om kaartlagen toe te voegen aan het Netwerk window kies het *Display Layers* icon van de Palette werkbalk. DMS toont het *Display Layers* dialoog scherm.

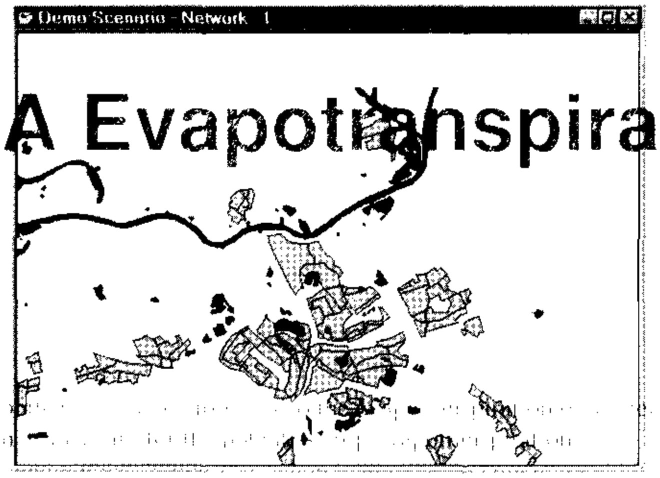
Gebruik de **Add** knop om kaartlagen toe te voegen aan het Netwerk. DMS opent het Open File dialoog scherm. Alleen Shape-bestanden kunnen gebruikt worden voor de kaartlagen in DMS. Selecteer het bestand **Water.shp**[1] uit de directory *Windflow\Projects\Shapes* in het File Open dialoog scherm. Dit Shape-bestand bevat de waterlopen van de Waal bij Den Bosch.

Nadat een Shape bestand is geselecteerd, toont DMS het Color dialoog scherm voor het selecteren van de juiste kleur - zeg blauw - voor de geselecteerde kaartlaag. Na de selectie van de kleur zal DMS terugkomen met het Display Layers dialoog scherm. De volgorde van de lagen in deze lijst correspondeert met de volgorde waarin ze worden getoond in het Netwerk window. Deze volgorde kan gewijzigd worden door een laag te selecteren en vervolgens op de **Up** of **Down** knop te drukken. Voeg nu ook het bestand **Cities.shp** toe aan de kaartlagen lijst. Dit bestand bevat de steden van het gebied.

[1] Geogafische achtergrond: Topografische ondergrond © Topografische Dienst, Emmen. De shape-bestanden Water.shp en Cities.shp zijn slechts voor demonstratie doeleinden te gebruiken.

Het Netwerk window zal er als volgt uit zien:

Appendix A Evapotranspiration



InZoomen

Gebruik het Inzoom mechanisme om gedeelten van de geografische achtergrond verder in detail te bekijken. Nadat dit commando is geselecteerd (uit het menu of vanuit de werkbalk), zal de cursor veranderen in een vergroot glas. Het slepen van het vergroot glas laat een rechthoek achter op het scherm. Deze rechthoek representeert het gebied dat vergroot zal worden (de rechthoek wordt uitvergroot totdat het Netwerk window gevuld is).

= *Bewaar het aktieve project*

Bewaar nu je activiteiten door middel van het *Save* commando van het *File* menu. Doe dit regelmatig !

= *Knoop*

= *Sectie*

Door middel van het slepen van de objecten van het Netwerk Palette, wordt het netwerk getekend. Kies het *Knoop* mechanisme van het palette, en klik op twee afzonderlijke posities in het Netwerk window. Kies vervolgens het *Sectie* mechanisme en klik met de linker muisknop op één van de twee knopen. Beweeg de muis door de *Sectie* te slepen van de ene knoop naar de andere.

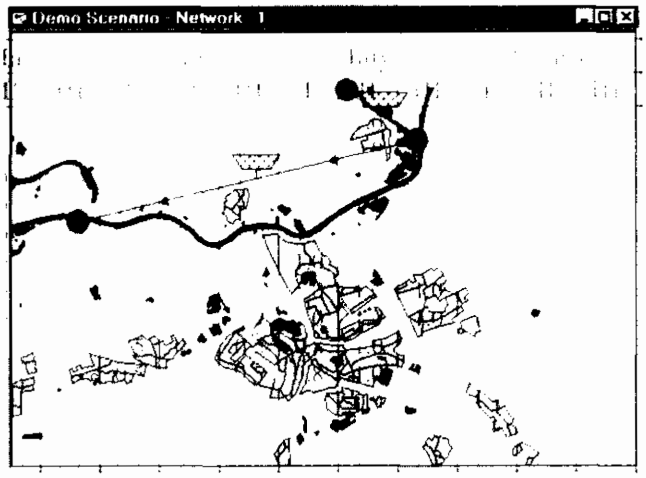
= *Selecteer object*

Als de lijn tussen de twee knopen gestippeld is, betekent dit dat de knopen niet goed verbonden zijn door de Sectie. De Knopen worden op een juiste manier verbonden door het *Selecteer* mechanisme (de pijl) van het palette te gebruiken. Pak het einde van de geselecteerde Sectie op en sleep deze richting de andere Knoop, totdat er een doorgetrokken lijn ontstaat tussen de twee Knopen.

= *Cross-Sectie*

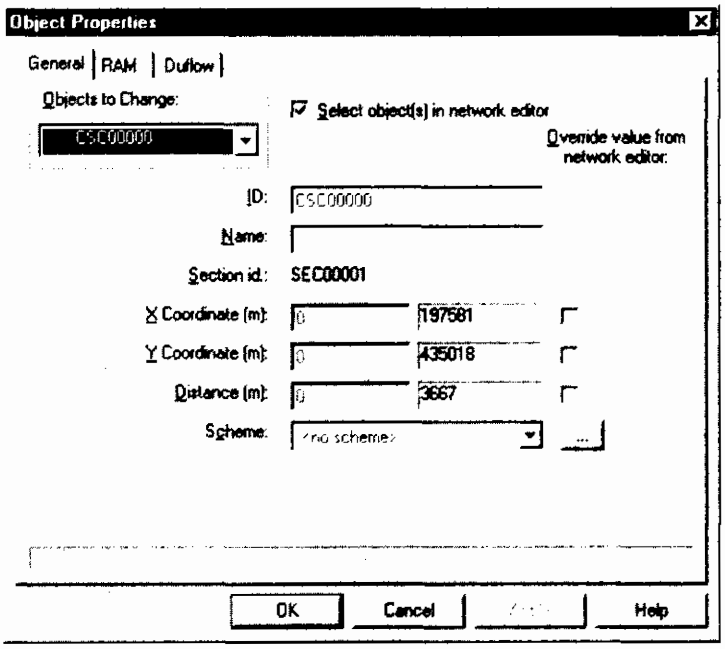
De profielen van dwarsdoorsneden worden aan de Sectie toegevoegd door het *Cross-Section* mechanisme van het palette te gebruiken. Als de gegevens over de dwarsdoorsnede gekoppeld zijn aan de Sectie, wordt dit mechanisme blauw. Als de *Cross-Section* niet juist aan de sectie is gekoppeld blijft het object gestippeld. Zolang er geen gegevens over de dwarsdoorsnede zijn ingevoerd blijft de *Cross Section* gearceerd.

Herhaal het bovenstaande proces totdat het volgende Netwerk ontstaat.



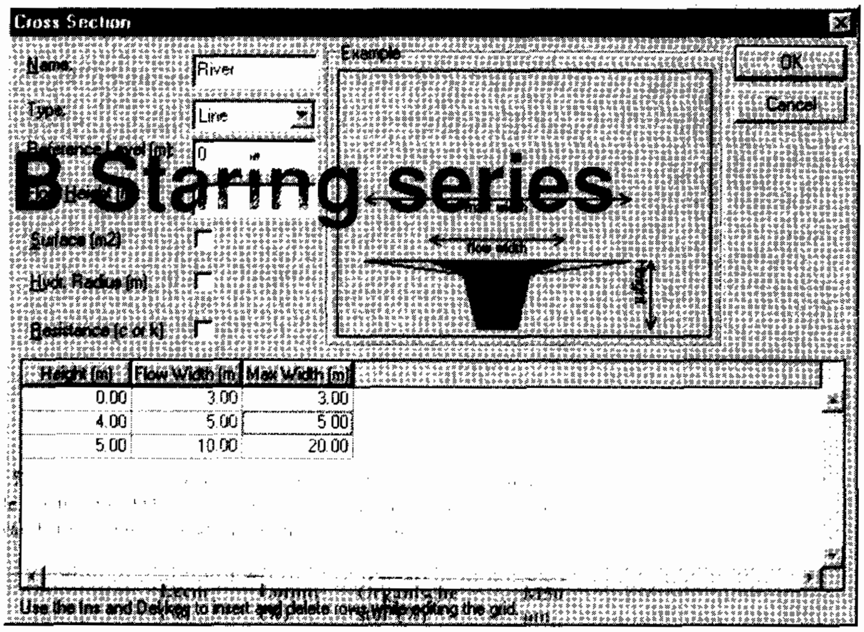
= *Object eigenschappen*

De profielen van dwarsdoorsneden worden gedefinieerd door gebruik te maken van schema's. Deze schema's moeten gekoppeld worden aan de *Cross-Sections*. Door met de rechter muisknop op één van de *Cross-Sections* te klikken, kies de *Properties* (Eigenschappen) optie uit het snelmenu.



In het *Object Properties* dialoog scherm, kan een schema gekoppeld worden aan de *Cross-Section*, er zijn echter nog geen schema's gedefinieerd voor dit Project. Een schema wordt aangemaakt door de **...** te kiezen achter het *Scheme* veld. In het *Cross Section Scheme* dialoog scherm, druk op **Add...** om het *Cross Section* dialoog scherm te tonen. Voer de volgende getallen in. Gebruik de **Ins** en **Del** toetsen voor het toe voegen of verwijderen van een rij.

Appendix B Staring series



Kies **OK**, **OK** en **OK**, het **River** schema is nu gekoppeld aan één van de *Cross-sections*.

= *Bewerk Eigenschappen van Netwerk objecten*

Nu kunnen we het **River** schema aan elke *Cross-Section* in het netwerk koppelen door de *Object - Properties* optie te kiezen uit het *Edit* menu. Het *Object Properties* dialoog scherm wordt nogmaals getoond, nu is het echter mogelijk om de eigenschappen van meerdere objecten tegelijkertijd te wijzigen.

Omdat DMS veel invoer gegevens nodig heeft, is het mogelijk om in één keer gegevens in te voeren voor meerdere objecten. In het *Objects to Change* combo veld kan men keizen van welk object de eigenschappen gewijzigd moeten worden.

Selecteer **All cross sections** van het *Objects to Change* combo veld en selecteer onder *Scheme* het schema **River** vanuit de keuze lijst. Klik **Ok** en alle *Cross-Sections* in het netwerk zijn nu gekoppeld aan hetzelfde schema. De *Cross-Sections* worden nu blauw.

= *Stuw*

Voeg nu een kunstwerk - hier een stuw (*weir*) - toe aan het netwerk, door de rode driehoek van het Netwerk Palette te gebruiken. Plaats de stuw als volgt in het Netwerk.

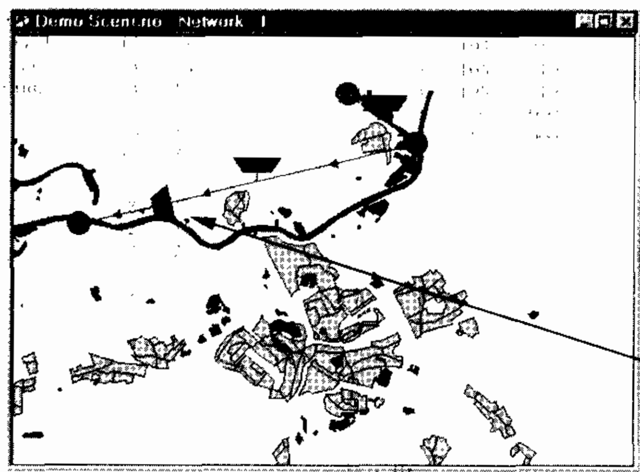
Andere kunstwerken:

= *Sifon*

= *Duiker*

= *Pomp*

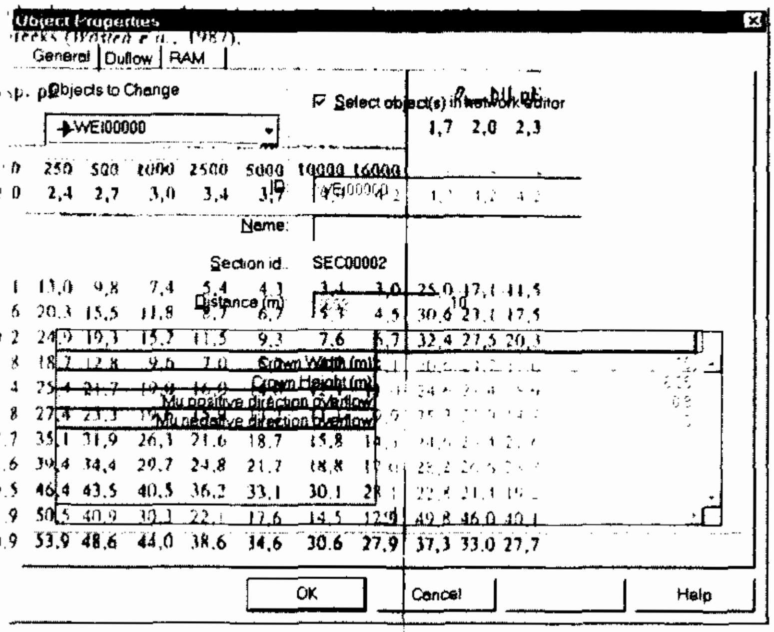
= *Algemeen kunstwerk*



Stuw

Op deze manier wordt er een kunstwerk toegevoegd aan het netwerk op de tweede sectie. Voordat de DUFLOW berekening van start gaat zal deze sectie automatisch in twee aparte secties worden opgedeeld.

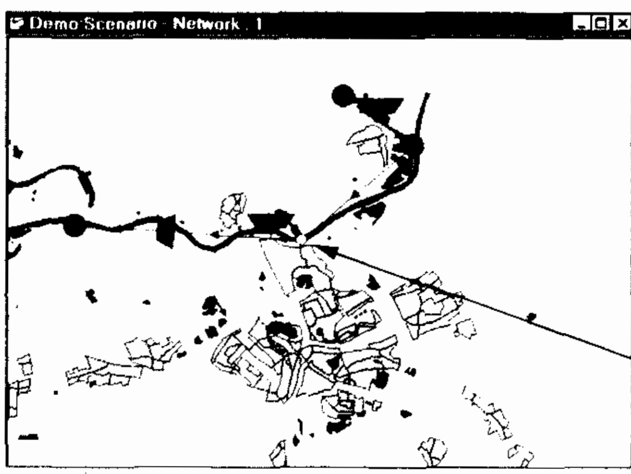
Klik met de rechter muisknop op de stuw om de eigenschappen als volgt in te vullen:



= *Schematisatie punt of buig punt*

Het is ook mogelijk om schematisatie punten toe te voegen aan het Netwerk. Na een berekening zullen de resultaten beschikbaar zijn op de knopen, de schematisatie punten en de rekenpunten. Rekenpunten worden gegenereerd door DUFLOW als de lengte van een sectie groter is dan de gedefinieerde maximale lengte. De maximale lengte van een sectie kan gedefinieerd worden onder het DUFLOW tab blad van het *Edit - Objects - Properties* dialoog scherm.

Schematisatie punten kunnen ook gebruikt worden om een sectie zodanig te vormen, dat deze meebuigt met het het verloop van de waterloop, zoals op de geografische achtergrond. Om een buig punt aan te maken moet eerst een schematisatie punt worden toegevoegd aan het netwerk. Vervolgens wordt het schematisatie punt geselecteerd, kies met de rechter muisknop de *Bending Point* optie uit het snelmenu. Door het buig punt te slepen naar de gewenste positie, wordt de sectie zo gebogen dat het de waterloop min of meer volgt.



Buig Punt

= *Lozings punt*

= *Oppervlakte punt*

Door een lozings punt aan een schematisatie punt toe te voegen, kan een tijd reeks van een debiet, vracht of concentratie gedefinieerd worden. Op een schematisatie punt kan ook een oppervlak gedefinieerd worden alwaar er met neerslag rekening gehouden kan worden.

Begin voorwaarden worden aan het netwerk toegevoegd door het *Initial Conditions* commando uit het Scenario menu te gebruiken. Voor alle Knopen en

Schematisatie punten kiezen we een initiële waterhoogte van 6 meter (boven het referentie niveau). Gebruik de **Set Column...** knop. Kies voor de kolom Level en vul de waarde in.

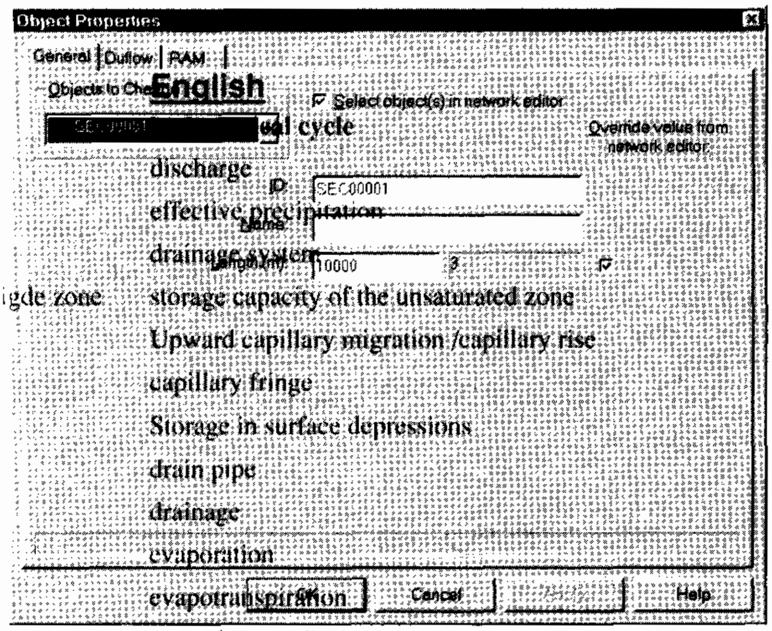
= *Bewerk Neerslag*

= *Bewerk Verdamping*

Appendix C Translation definitions

Na het definiëren van een schematisatie punt, kan een Neerslag tijd reeks gezet, geïmporteerd of aangepast worden door middel van het *Precipitation* dialoog scherm. Deze wordt geopend door de *Precipitation* optie te kiezen uit het Scenario menu. Op dezelfde wijze kan een Verdamipings tijd reeks gezet, geimporteerd of aangepast worden door middel van het *Evaporation* dialoog scherm.

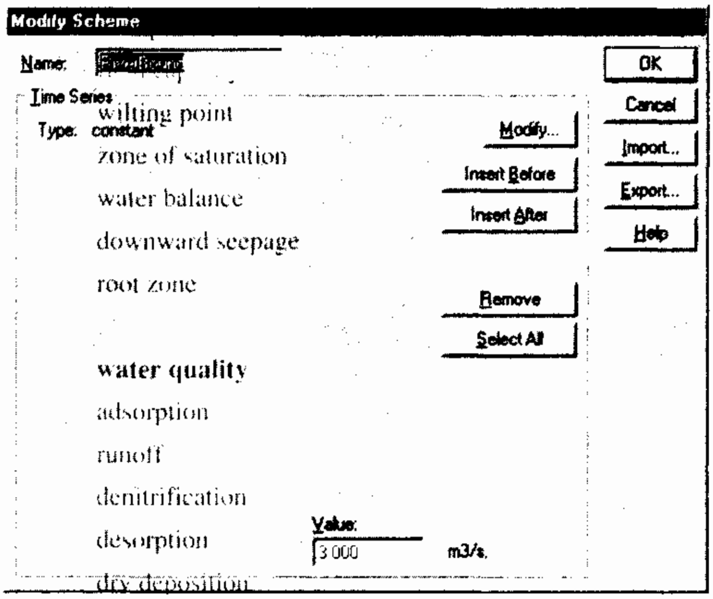
Momenteel wordt de lengte van de Secties berekend door de Netwerk editor aan de hand van de onderlinge posities van de Knopen. Om het ontworpen netwerk meer realistisch te maken, kunnen we deze Sectie lengtes ook overschrijven door zelf gedefinieerde waarden. Voor elke Sectie kan de waarde van de lengte als volgt aangepast worden in het *Section Object Properties* dialoog scherm:



Dutch	English
hydrologische kringloop	**hydrological cycle**
afvoer	discharge
afvoerbare neerslag	effective precipitation
afwateringsstelsel	drainage system
bergingscapaciteit van de onverzadigde zone	storage capacity of the unsaturated zone
capillaire opstijging	Upward capillary migration /capillary rise
capillaire zoom	capillary fringe
depressieberging	Storage in surface depressions
drain	drain pipe
drainage afvoer	drainage
evaporatie	evaporation
evapotranspiratie	evapotranspiration
grondafvoer	ground water discharge
grondwaterstand	ground water level
grondwaterstandsdiepte	depth of the groundwater level
hydrologische kringloop	hydrologic cycle
infiltratie	infiltration
infiltratiecapaciteit	infiltration capacity
interceptie	interception
kwel	seepage / exfiltration
neerslag	precipitation
neerslagintensiteit	precipitation intensity
neerslagoverschot	precipitation
netto neerslag	precipitation excess
onverzadigde zone	unsaturated zone
ontwatering	drainage
oppervlakte afvoer	surface runoff
percolatie	percolation
schijnspiegel	perched water table / apparent water table
schijnspiegelafvoer	interflow

Nu zetten we op de eerste Knoop een randvoorwaarde. Randvoorwaarden worden gedefinieerd door eerst de juiste Knoop te selecteren en vervolgens het *Object Properties* dialoog scherm op te roepen voor deze Knoop. Druk op de **Boundary Conditions...** knop. Het *Boundary Condition* dialoog scherm wordt getoond. Er moeten echter eerst nog randvoorwaarde schema's worden aangemaakt.

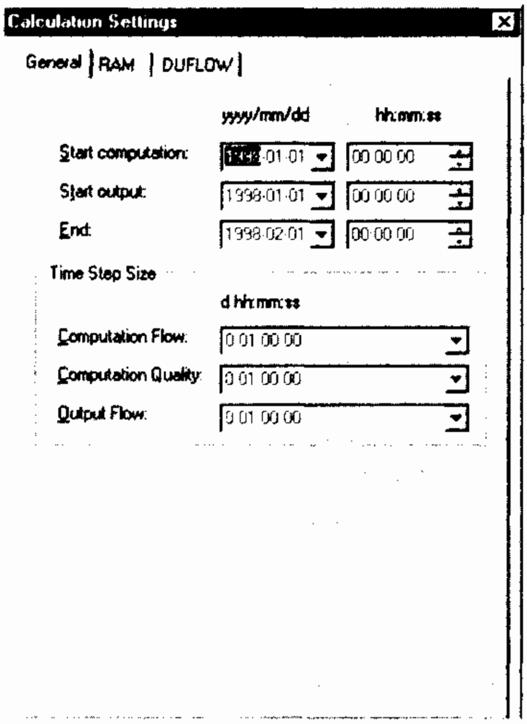
Om een Debiet schema in te voeren, druk op de ... achter het *Q-add* veld. Kies vervolgens de **Add...** knop en voer het volgende schema in:



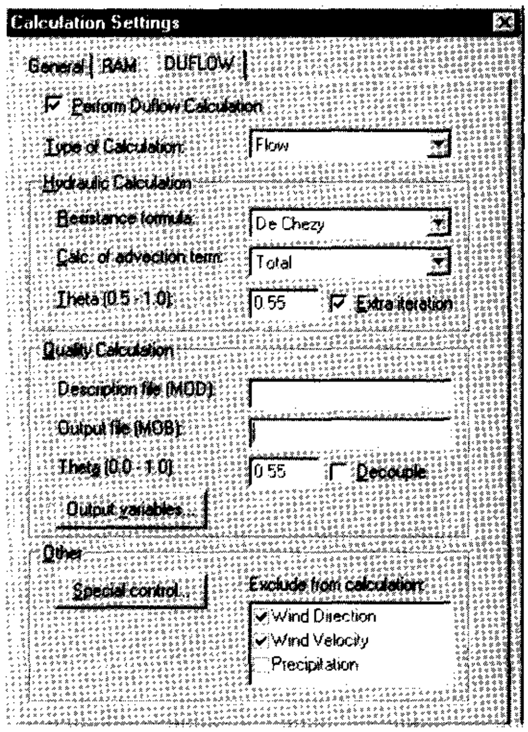
Kies **OK** en **OK** en het *Q-Add* Schema is nu ingevoerd op Knoop 1. Herhaal deze acties om een constant waterpeil van 6 meter op te geven als randvoorwaarde aan het andere eind van het Netwerk.

2.3. Definieer en start de berekening

Alvorens de berekening te starten, controleer de invoer van het *Calculation Settings* dialoog scherm. Dit scherm wordt geactiveerd door de rechter muisknop op Calculation Settings in de Scenario manager. Het General settings tab blad zet het begin en eind punt van de simulatie en de grootte van de kwantiteits- en kwaliteits tijdstap. Voer de gegevens als volgt in:



Op het DUFLOW tab blad is het mogelijk om DUFLOW-specifieke simulatie opties te definiëren.



Hier kan gekozen worden voor het type berekening. Voer allereerst een **Flow** berekening uit om te controleren of het Network juist ontworpen is. Als de **Flow** berekening eenmaal geverifieerd is, kan een kwaliteits model toegevoegd worden. In dit dialoog scherm worden de details van de kwantiteits en kwaliteits berekening gezet. Men kan hier de naam van het het *Quality model definition* bestand invoeren. Zorg ervoor dat dit bestand geplaatst is in de Scenario directory.
Door op **Output Variables...** te drukken, kunnen de variabelen van het kwaliteits model geselecteerd worden voor uitvoer.
In Special Control worden de speciale stuur gegevens ingevoerd, zoals het drempel niveau, dat aangeeft bij welk waterpeil het droogval mechanisme geactiveerd zal worden. (Standaard=0.10 m).

 = *Bereken*

De berekening wordt geactiveerd door de *Update All* optie uit het *Calculation* menu (óf de *Calculate* knop van de werkbalk óf de *Calculate* optie van het Scenario snelmenu). Het *Output* window toont het initialiseren van de berekening. Het zou er als volgt uit kunnen zien:

```
Starting network consistency check...
Starting Duflow conversion...
Duflow conversion completed.
Writing boundary flow file C:\Winduflow\Examples\Demo\Scenario\scenario.BND.
Writing network file C:\Winduflow\Examples\Demo\Scenario\scenario.NET
Writing initial flow file C:\Winduflow\Examples\Demo\Scenario\scenario.BEG.
Computing mode: Flow
```

De *Status Balk* toont het verloop van de berekening in tijdstappen. Het zou er als volgt uit kunnen zien:

```
Computing flow 124( 744)
```

 = *Maak Output zichtbaar*

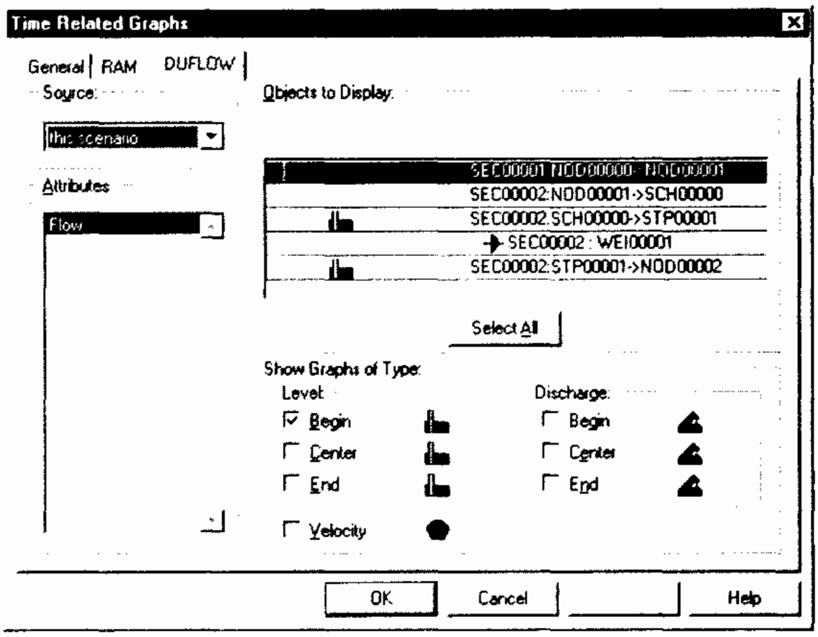
Het *Output* window wordt zichtbaar (of verdwijnt) door middel van de *Output* optie uit het *View* menu.

2.4. Tonen van de resultaten

Resultaten kunnen op drie verschillende manieren getoond worden:

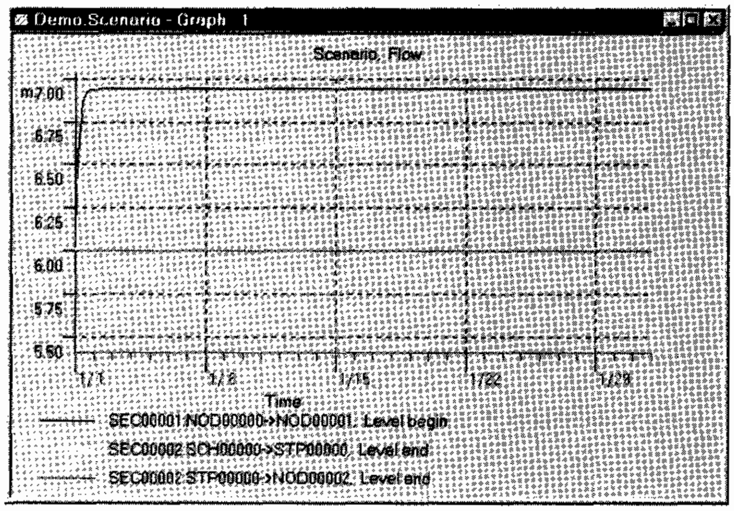
- Een Tijd afhankelijke grafiek,
- een Ruimte afhankelijke grafiek of
- resultaten als Tekst in een tabel als functie van de tijd.

Door de *New Time Graph window* optie te kiezen van het Scenario snelmenu, worden de resultaten weergegeven in een grafiek als functie van de tijd. DMS opent het *Time Related Graph* dialoog scherm. Op het DUFLOW tab blad is het mogelijk om aan te geven welke variabelen op welke secties getoond moeten worden.



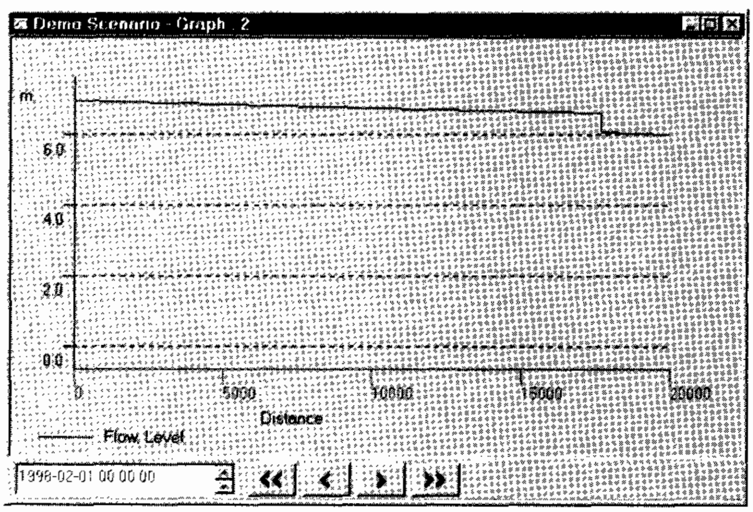
Gebruik **Show Graphs of Type** om te kiezen welke grootheid weergegeven moet worden (Waterniveau, Debiet of Snelheid) van de geselecteerde Sectie gebieden in de **Objects to Display** lijst. Na het maken van een keuze wordt een grafiek getoond. Deze grafiek toont het data type dat aangeklikt is in de rij(en) van de geselecteerde Secties, uitgezet tegen de tijd. Het selecteren van data type voor de grafiek is ook mogelijk door met de linker muisknop op de gewenste secties de linker kant van de rij aan te klikken. De plaats in de rij correspondeert met de volgorde van de Type lijst.

Als de keuze als in het bovenstaande dialoog scherm is aangeklikt, zal DMS de volgende grafiek tonen:



Door de *Space Graph window* optie van het Scenario snelmenu te kiezen worden de resultaten ruimtelijk getoond. DMS zal het *Space Related Graph* dialoog scherm openen. Allereerst moet de route die de grafiek door de secties heen moet lopen gedefinieerd worden. Dit gebeurt door het achtereenvolgens dubbel klikken op de gewenste secties. Een route bestaat uit één of meerdere secties. Nadat de route is gedefinieerd en geselecteerd, kunnen de gewenste variabelen aangeklikt worden. Door de knoppen onderaan de grafiek aan te klikken kan de grafiek in het Space Related Graph window vooruit en achteruit in de tijd doorlopen worden.

De uiteindelijke ruimtelijke grafiek ziet er dan als volgt uit:



Om de resultaten als tekst weer te geven in een tabel kies voor de *New Text window* optie vanuit het Scenario snelmenu. DMS opent het *Time Related Graph* dialoog scherm. Onder het DUFLOW tab blad wordt gedefinieerd welke variabelen op welke secties weergegeven moeten worden in de tabel.

2.5. Kwaliteits model

Om een Kwaliteits model toe te voegen aan een bestaande Kwantiteits model, moeten de voglende acties ondernomen worden.

2.5.1. Definieer het Kwaliteits Model

Om een Kwaliteits model toe te voegen aan het Project gaan we naar de DUFLOW tab van het *Calculation Settings* dialoog scherm. Hier voeren we, beiden zonder extensie, de naam in van het *Quality Model description* bestand (*.MOD) en de naam van het *Quality Model Output* bestand (*.MOB). Vul in beide velden, bijvoorbeeld de naam 'Tracer' in. Als het Quality Model bestand, zoals hier het geval is, nog niet aanwezig is in de Scenario directory, zal DMS een melding geven om dit bestand aan te maken.

Een eenvoudige *Quality Model description* bestand zoals hieronder bevat de definitie van een 'tracer':

```
/* DUFLOW COURSE FEBRUARY 1998                                           */
/* SIMPLE TRACERMODEL                                                    */
/* HINNE PEITSMA 02-01-1998                                              */

WATER   TRAC   [10.000]   mg/l        ;TRACER

PARM    Ktrac  [0.0100]   1/day       ;DECOMPOSITION RATE TRAC

{
K1(TRAC)=-Ktrac;
}
```

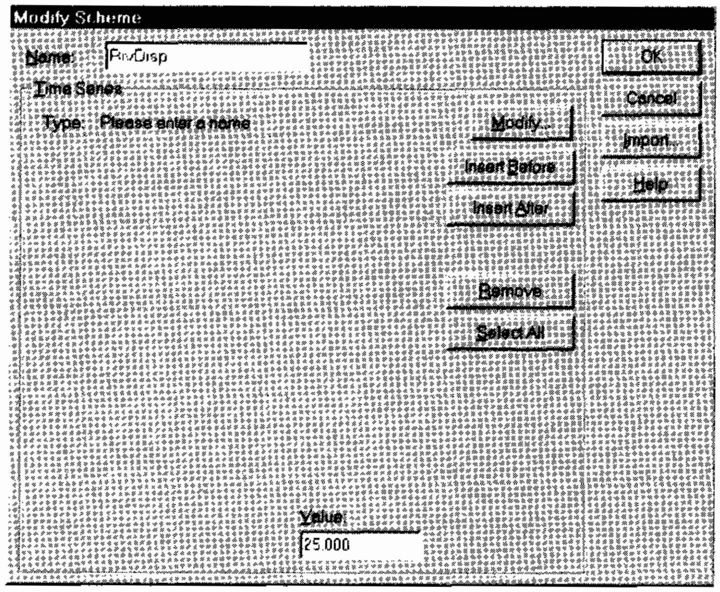
Deze beschrijving kan in het *Quality Model description* bestand worden ingevoerd door het *Quality Model - Edit* commando te kiezen uit het Scenario menu. Als deze definitie juist ingevoerd is, wordt het gecompileerd door het *Quality Model Compile* commando te kiezen uit het Scenario menu.

2.5.2. Begin Voorwaarden

Nu het kwaliteits model gedefinieerd is, willen we ook de begin voorwaarden hiervoor invullen. Begin voorwaarden worden ingevoerd door het *Initial Conditions* commando te kiezen uit het Scenario menu. Voor alle Knopen en Schematisatie punten zetten we een initiële concentratie voor **Trac** van 10 mg/l. Dit doen we door middel van de **Set Column...** knop. Kies de kolom **Trac** en voer de waarde in.

2.5.3. Externe Variabelen

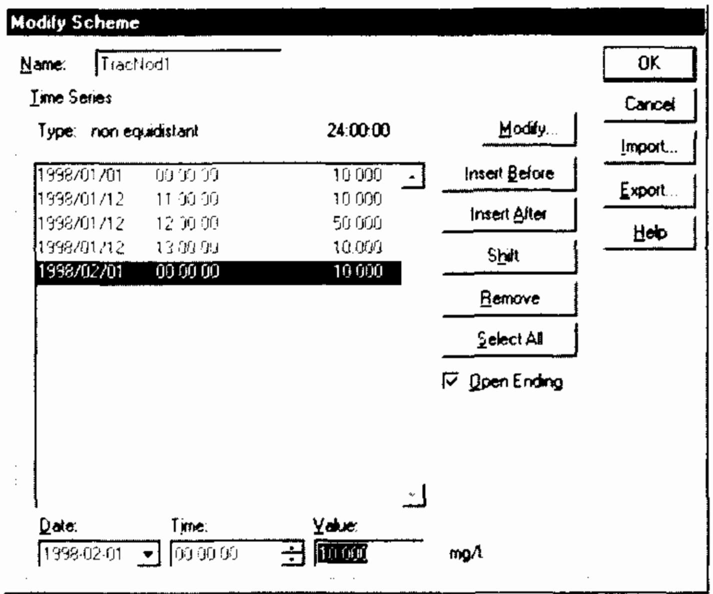
Dispersie is een externe variabele die in elke Kwaliteits model gedefinieerd moet worden. We voegen een externe variabele toe door middel van de rechter muisknop op External Variables in de Scenario Manager. Selecter de externe variabele '**d**' van het *Modify External Variables* dialoog scherm en kies dan **Modify...**. Kies vervolgens **Add...** in het *Select Scheme* dialoog scherm om het volgende schema voor dispersie (d) in te voeren:



Nadat het schema voor de Externe Variabele is aangemaakt moet dit schema gekoppeld worden aan elke Knoop, Schematisatie punt en Kunstwerk. In dit voorbeeld gebruiken we het schema **RiverDisp** voor elke object in het netwerk. Open het *Object Properties* dialoog scherm door te kiezen *Edit - Object - Properties*. Selecteer vervolgens *All Nodes* en druk op de **External Variables...** knop van de DUFLOW tab. Achter de External Variable '**d**' kan nu het **RiverDisp** schema geselecteerd worden. Herhaal deze acties voor het Schematisatie punt en het Kunstwerk.

2.5.4. Randvoorwaarden

De eerste Knoop heeft ook een Kwaliteits randvoorwaarde nodig. Haal het *Properties* dialoog scherm van de eerste knoop tevoorschijn. Druk op de **Boundary Conditions...** knop van het General tab blad. Klik op de **...** knop achter **Trac** om een *Boundary Condition Scheme* tor **Trac** te definieren. Druk op **Add...** in het *Select Scheme* dialoog scherm om een nieuwe tijd reeks te definieren. Verander het type randvoorwaarde naar *non-equidistant*. Vul de volgende tijd reeks in:



Herhaal bovenstaande stappen om een constante concentratie van 10 mg/l te definieren als randvoorwaarde aan het andere einde van het Netwerk. Een kwaliteits randvoorwaarde geldt alleen voor het instromende water.

Noot: Een kwantiteits randvoorwaarde zonder een kwaliteits randvoorwaarde heeft een speciale betekenis, die de berekenings resultaten kan beïnvloeden. In normale situaties is het daarom noodzakelijk om een kwaliteits randvoorwaarde voor elke kwantiteits randvoorwaarde te definiëren, zelfs als er slechts sprake van uitstromend water op de rand.

2.5.5. Definieer Berekening

Alvorens de berekening te starten, moet eerst de invoer van het *Calculation Settings* dialoog scherm gecontroleerd worden. Dit scherm wordt geactiveerd door middel van de rechter muisknop op *Calculation Settings* in de Scenario manager.

Kies nu voor *Type of calculation:* **Flow&Quality**. Zet in *Output Variables* de variabele **Trac** aan voor het wegschrijven van resultaten.

 = *Bereken*

De berekening wordt geactiveerd door middel van de *Update All* optie uit het *Calculation* menu (of de *Calculate* knop van de werkbalk of de *Calculate* optie uit het Scenario snelmenu). Het *Output* window en de Status balk geven het verloop van de berekening weer.

Als het model kwaliteits randvoorwaarden bevat zonder bijbehorende kwantiteits randvoorwaarden, zullen er waarschuwingen gegenereerd worden in het *Output* window.

2.6. RAM

De hierna volgende stappen kunnen slechts uitgevoerd worden met een juist geïnstalleerde RAM component.

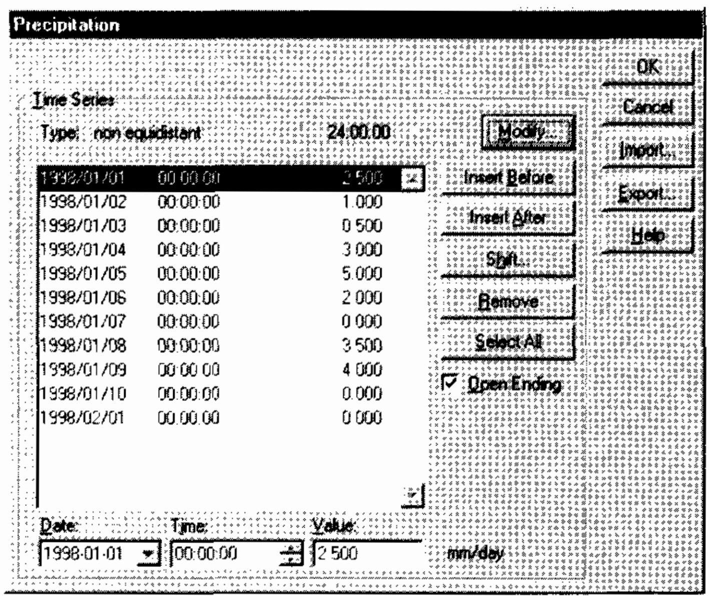
2.6.1. Neerslag en Verdamping

Een belangrijk onderdeel van de benodigde invoer voor RAM is de neerslag en verdamping. Om deze gegevens in te voeren, moeten de volgende stappen ondernomen worden.

 = *Bewerk Neerslag*

Kies het *Precipitation* commando uit het Scenario menu. DMS opent het *Precipitation* dialoog scherm. In dit dialoog scherm kan een Neerslag tijd reeks ingevuld worden. Druk eerst op de **Insert Before** knop om het begin van de tijd reeks in te voeren. Druk vervolgens op de **Shift...** knop om het *Shift Values* dialoog scherm te openen en verander de start datum en tijd van de tijdreeks naar 1 januari, 1998 onder *Set New Start Date & Time*. Terug op het *Precipitation* dialoog scherm, druk op de **Insert After** knop. DMS voegt een nieuwe regel toe aan de lijst. Herhaal deze actie 10 keer. Selecteer de eerste regel van de lijst. DMS springt automatische naar het **Value** veld waar een waarde voor de Neerslag in mm/dag ingevuld kan worden.

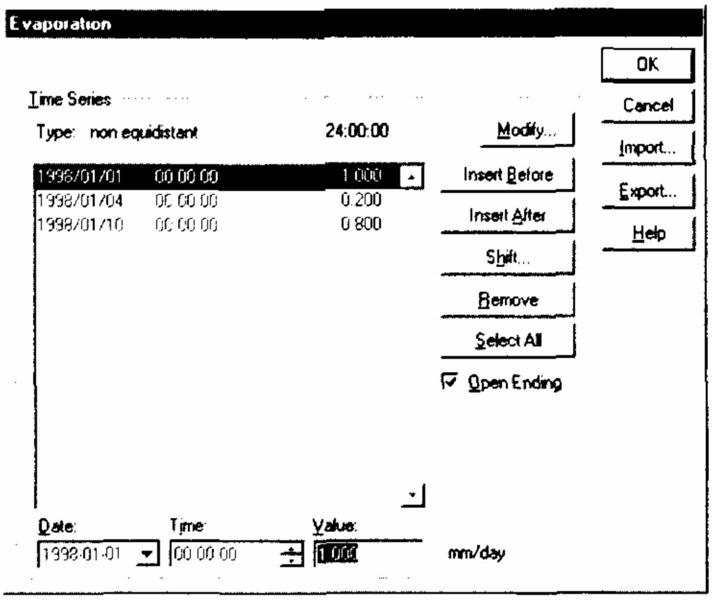
Vul de volgende waarden in:



We willen de Duflow berekening laten beginnen in januari 1998.

= *Bewerk Verdamping*

Herhaal bovenstaande stappen om de Verdamping te definieren. Vul de volgende waarden in:



Noot: Omdat de datum en tijd van de tijdreeks in oplopende volgorde ingevuld moet worden, moet eerst de allerlaatste datum aangepast worden alvorens de tweede datum naar 1998/01/04 te wijzigen. Als dit in de verkeerde volgorde wordt uitgevoerd, verschijnt er een foutmelding.

2.6.2. Definieer het Oppervlak

= *Oppervlakte punt*

Om het de afvoer van de vrachten naar een Knoop in het netwerk uit te rekenen, heeft RAM invoer nodig over het oppervlak rondom de desbetreffende Knoop. Allereerst moet een oppervlak (*Area*) in het netwerk gedefinieerd worden. Een Area wordt altijd gekoppeld aan een Schematisatie punt. Om een Area toe te voegen aan het Netwerk, sleep het Area object van de *Palette* werkbalk naar het Schematisatie punt. Als de Area gekoppeld is aan het Schematisatie punt, zal het groen oplichten, anders zal het gestippeld blijven.

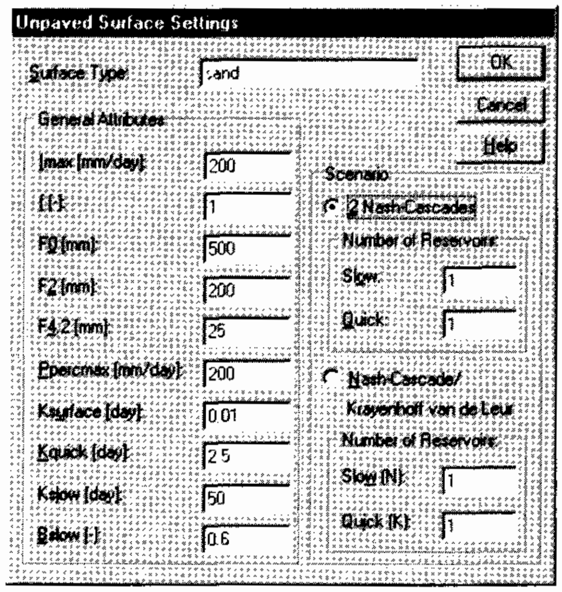
Dubbelklik op het Area object in het Network window om de eigenschappen op te geven. DMS toont het *Object Properties* dialoog scherm. Op het General tab blad kan het totale oppervlak (*Total surface*) van het gebied opgegeven worden. In dit geval is de oppervlakte 10000 ha (1e+8 m²). Selecteer het RAM tab blad om de RAM-specifieke gegevens op te geven.

De gegevens voor de Area zijn onderverdeeld in logische categorieën. Een categorie kan geselecteerd worden uit de lijst. Selecteer de categorie *Area* en specificeer het percentage *Unpaved surface* op 100%.

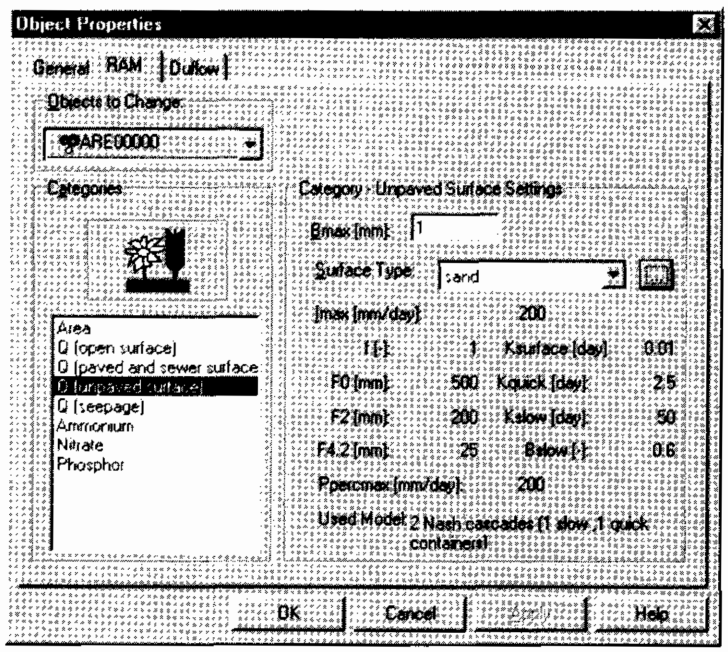
Selecteer *Q (unpaved surface)* van de Categorie lijst. DMS toont de Unpaved Surface gegevens aan de rechterkant van het dialoog scherm. Omdat de gegevens van de Unpaved Surface nogal uitgebreid zijn en omdat ze afhankelijk zijn van het type oppervlak, is het mogelijk om in RAM met schema's te werken. Hierdoor is het mogelijk om de Unpaved Surface invoer gegevens opnieuw te gebruiken voor andere Knopen.

Kies de [...] knop aan de rechter kant van *Surface Type*. DMS toont the *Select Unpaved Surface Scheme* dialoog scherm. Omdat er nog geen schema's bekend zijn, creëren we hier een nieuwe.

Druk op de **Add...** knop. DMS toont het *Unpaved Surface Settings* dialoog scherm. Vul de volgende waarden in:



Druk op **OK**. Druk op de **OK** knop in het Select *Unpaved Surface Scheme* dialoog scherm. DMS toont de waarden van het Unpaved Surface schema in het *Objects Properties* dialoog scherm als de categorie *Q (Unpaved surface)* gekozen wordt.



Gegevens voor andere categorieën kunnen op dezelfde manier ingevuld worden. Voor het geval van Ammonium, Nitrate and Phosphor, gebruikt RAM ook schema's. In feite zijn deze schema's tijd reeksen en kunnen worden ingevoerd door middel van dialoog schermen die lijken op de *Precipitation* en *Evaporation* dialoog schermen.

2.6.3. Berekenen

Alvorens de berekening op te starten, controleer de invoer van het *Calculation Settings* dialoog scherm. Het General tab blad geeft het begin tijdstip en grootte van de tijdstap voor de kwantiteit- en kwaliteit simulatie. Vul nu dezelfde simulatie periode in, als gebruikt voor Neerslag en Verdamping. (van 1 tot 10 januari 1998).

Zet, onder het RAM tab blad, de *Perform RAM Calculation* optie aan. De *Perform Duflow Calculation* optie van het Duflow tab blad zal tegelijkertijd uitgeschakeld worden.

 = *Bereken*

De berekening wordt opgestart door middel van de *Update All* optie van het *Calculation* menu. Het *Output* window en de Status Balk tonen het verloop van de berekening.

Als de simulatie afgelopen is, heeft RAM een randvoorwaarde gegenereerd voor het additionele debiet op het Schematisatie punt waaraan het Area object is gekoppeld. Om deze randvoorwaarde te bekijken, dubbel klik op het Area object in het Netwerk window. DMS opent het *Object Properties* dialoog scherm. Druk op de **Boundary Conditions ...** knop. Druk achter het QAdd schema deze is aangemaakt door DMS. Kies **Modify...** om de tijd reeks te tonen die deze randvoorwaarde voorstelt.

Wordt een Duflow berekening nu opnieuw uitgevoerd, dan zullen de resultaten verschillend zijn.

Als een Duflow berekening opgestart wordt na en RAM berekening, laat de Neerslag buiten beschouwing tijdens de Duflow berekening (*Calculation Settings* - Duflow tab blad). Als dit niet gebeurt, zal de Neerslag twee keer worden meegenomen in de berekening.