

DUFLOW for Windows V3.3

Duflow Modelling Studio

- User's Guide

- Reference Guide Duflow

- Reference Guide RAM

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TEN GELEIDE

Met versie 3.3 is er eveneens geheel herziene handleidingen van DUFLOW beschikbaar. Zowel de **User's Guide DUFLOW MODELING STUDIO**, de **Reference Manual DUFLOW** als de **Reference Manual RAM** zijn vernieuwd. Daarnaast is er een nieuwe versie van het rapport **DUFLOW Waterkwantiteits proces beschrijvingen** uitgekomen. Alle handleidingen worden automatisch gezonden naar de DUFLOW gebruikers met een abonnement op de Gebruikersondersteuning & Updates regeling.

In User's Guide is niet alleen aangepast aan de functionele wijzigingen in de afgelopen versies van DMS. Op veel onderdelen is de toelichting verder uitgebreid na aanleiding van vragen van gebruikers. De werking van de Scenario Manager en de Presentation Mode is ruim opgezet waarbij tevens voorbeelden zijn opgenomen. Aan het opzetten van een Kwaliteitsmodel op basis van een bestaand Kwantiteitsmodel is een nieuwe hoofdstuk gewijd. De hoofdstuk indeling van de User's Guide komt overeen met de opbouw van een model in DUFLOW.

De Reference Manual van DUFLOW geeft nu ook een beschrijving van het bestandsformaat versie 3.0. Eveneens wordt in het hoofdstuk DUPROL ingegaan op de werking van de variabele dispersie en zuurstof inslag in een kwaliteitsmodel. De Reference Manual RAM is sterk uitgebreid door de functionele uitbreidingen m.b.t. de onverzadigde zone en de mogelijkheden bij het verharde oppervlak.

Internet site

DUFLOW heeft sinds kort een eigen internet domein **WWW.DUFLOW.NL !!!**

Vanaf de DUFLOW site kan de allernieuwste versie van DUFLOW worden gedownload. Gebruikers met een abonnement op de Gebruikersondersteuning & Updateregeling kunnen de wachtwoorden voor de installatie van de volledige versie aanvragen bij de DUFLOW helpdesk. Meer informatie over de DUFLOW helpdesk staat uiteraard ook op de internet site.

De werkzaamheden zijn uitgevoerd door EDS met als projectleider ir. H. Reitsma. Het project is vanuit de STOWA begeleid door ir. J.J. Noort en ir. L.R. Wentholt.

Utrecht, augustus 2000

De directeur van de STOWA

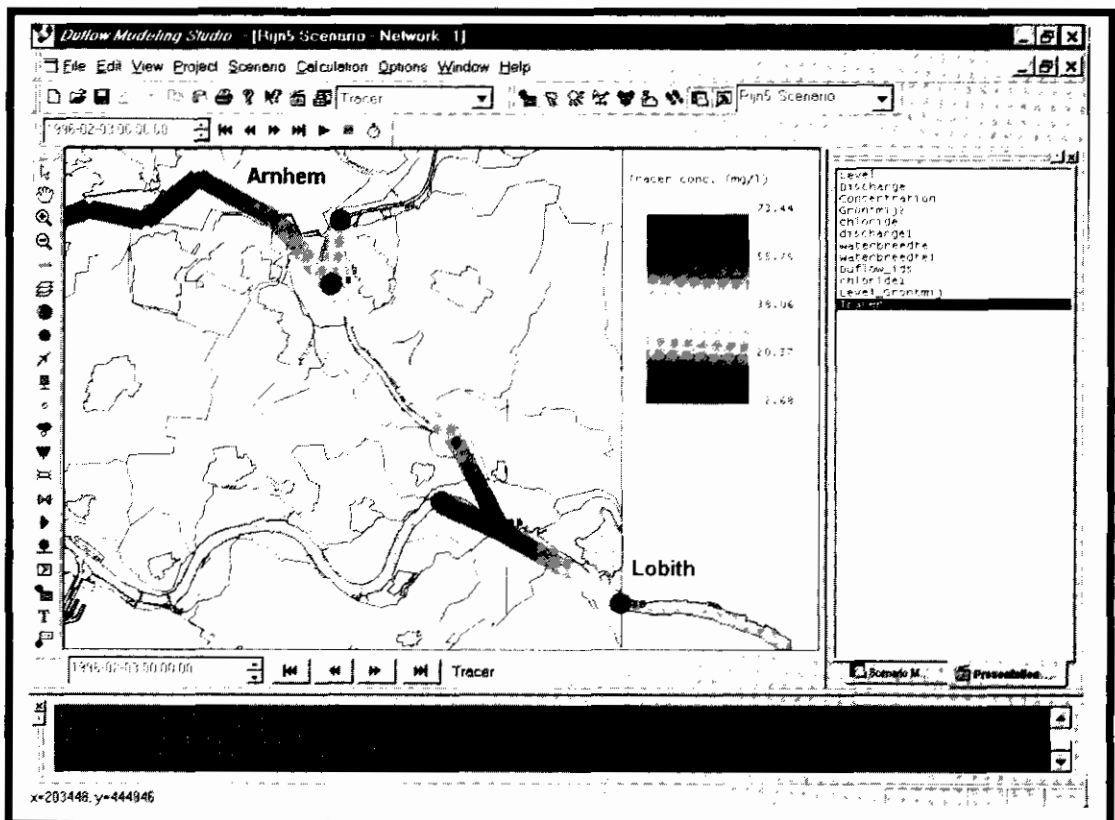
Ir. J.M.J. Leenen

Duflow Modelling Studio

User's Guide

VERSION 3.3 February 2000

Stowa / EDS



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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 watercourses. 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 (implemented in DMS version 3.4)**
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 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, area points, discharge points and objects containing cross sectional data, etc.

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.

1.1.2 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 however can 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 open projects and scenarios.

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 hairline. 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.
- Results of the Duflow calculation can be spatially visualised in the Network using 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; not only at the begin or end of the section like in Duflow 2.0x. The floor level (bottom) 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 C:\duflo.exe. The numbers of the nodes and sections in these ASCII files do not 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, Windows98 or WindowsNT (4.00 or higher)

1.3 Internet

More and recent information about DufLOW can be found at the DufLOW Internet site:

www.dufLOW.nl

1.4 Installation

The DufLOW Modelling Studio consists of Setup files, a User's Guide and a Reference Manual for each component. The files can be downloaded from the Internet.

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, oex) 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 installation procedure of the DufLOW Modelling Studio is also described on the Internet.

1.5 DUFLOW Helpdesk

Users of DMS can subscribe to the DufLOW helpdesk. Users may contact the helpdesk when encountering problems while using DMS. Support will only be given to users with a subscription on User Support and Updates (U&U). When the user enrolls 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 DufLOW Users day is organised. During this activity users may present their results of using the DMS package. This DufLOW users day is particularly focused on the mutual acquaintance between users. Attendees of these days are informed about the latest DufLOW developments.

1.6 Courses

Delft courses are regularly organised by the *ITE*, which usually take place in the course of 2 to 5 days. The course is divided into the modules of DMS with respect to water quantity problems, water quality problems and the use of the precipitation runoff model.

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 DMS package

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 Duflow component must be installed correctly.

2.1 Define a Project

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

Identification		
Name Project	Name 1st Scenario	
Demo	Scenario	

Location:

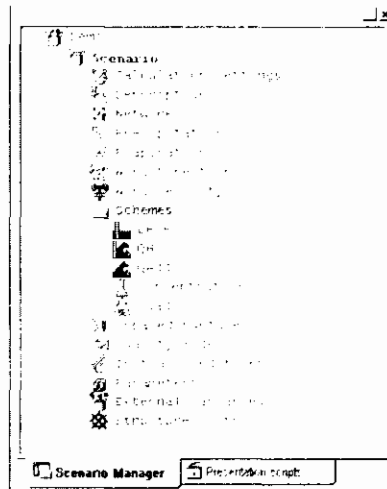
C:\windflow\projects\Demo Browse...

Initial Position


X Coordinate:	Y Coordinate:	Number of Meters per pixel
140000	400000	100

Choose the name of a Project, say **Demo**. A project contains **one** or more scenarios. The location of the directory of the project may be altered in the *Location* field. A sub-directory for the first scenario – base scenario - is automatically created by DMS in the Project directory. Enter real values for the co-ordinates as shown in the figure. When you build a schematization of the water system in the so-called Network window, the left-handed bottom corner of that window represents these initial co-ordinates. By choosing *Create*, a new project is built.

DMS will now open the window, known as the *Workspace Manager*, which contains the *Scenario Manager*.




This window shows all currently open Projects, 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 *Workspace Manager*


If the *Workspace Manager Window* is hidden you can call it by choosing the option *Workspace 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 Building the Network


 = Open Network window

Use the *Open Network window* command in the *View* menu to open the Network window. In this window a network schematization can be 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

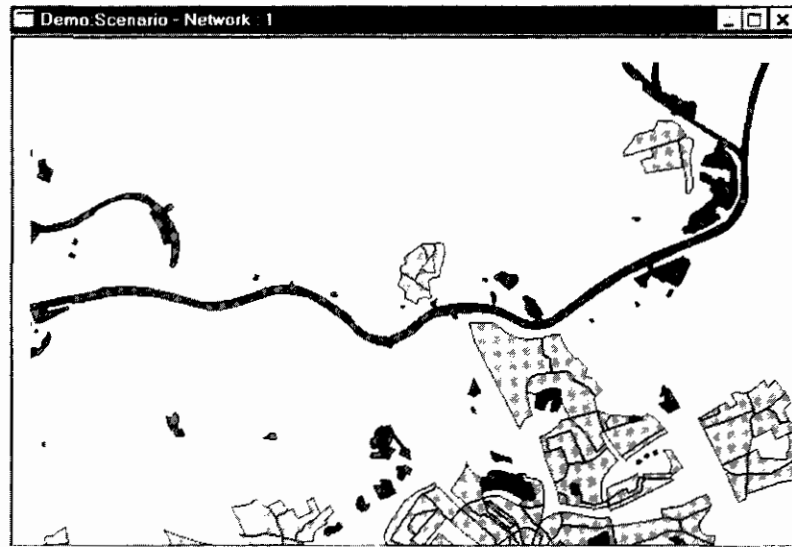
To add layers to the Network window choose the *Display layers* icon on the *Palette* toolbar. DMS will show the *Display Layers* dialog box.


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 *WinDufLOW/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 corresponds 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).


 = *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. The length of the sections is calculated by the Network editor based on the positions of the Nodes.

 = *Select object*

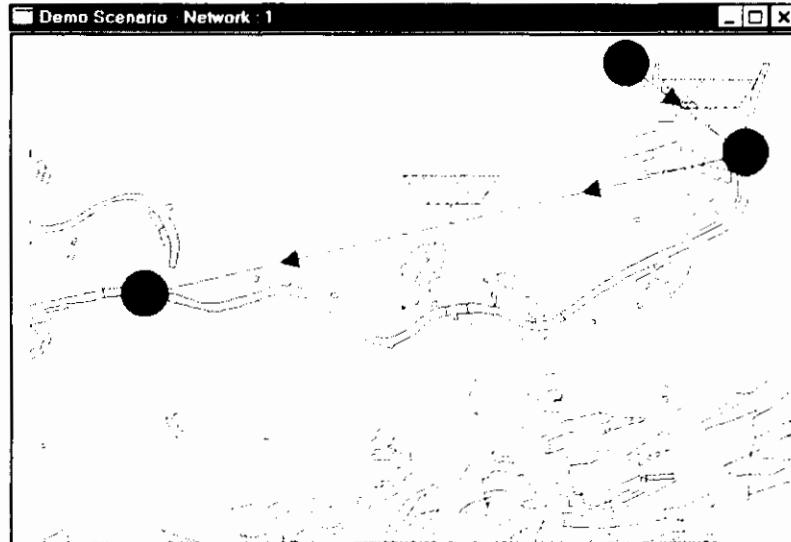
If the line between two nodes remains dotted, it means that the Nodes are not correctly connected by the Section. The Nodes can be properly connected by using the *Select* tool (the arrow) from the palette and dragging the end of the selected Section until the line is complete.


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

 = Cross Section

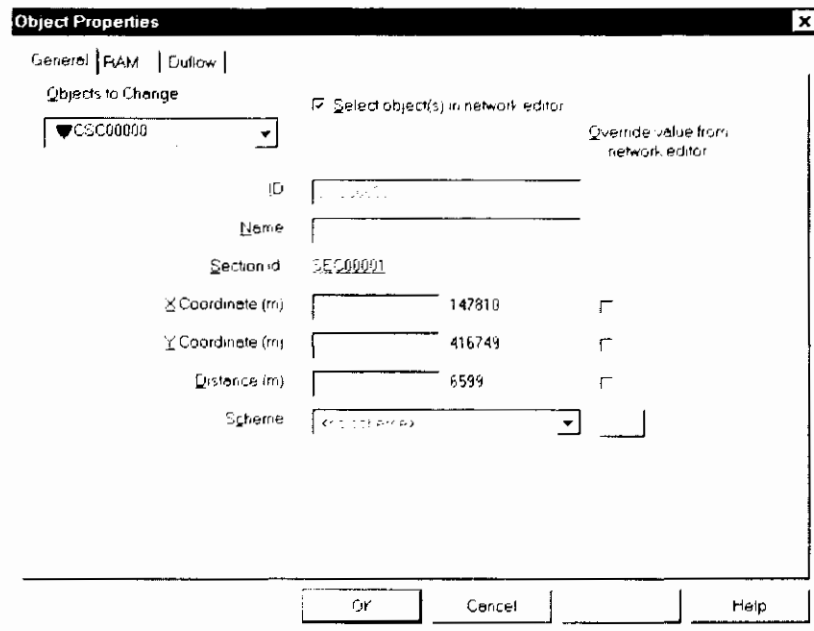
Cross Sections are added to the Section by using the *Cross Section* tool from the palette. When the cross sectional data is connected to the section it appears cross-hatched red. If the *Cross Section* is not properly connected to the section, its outline will remain dotted.

Repeat the above process until the following network is created:

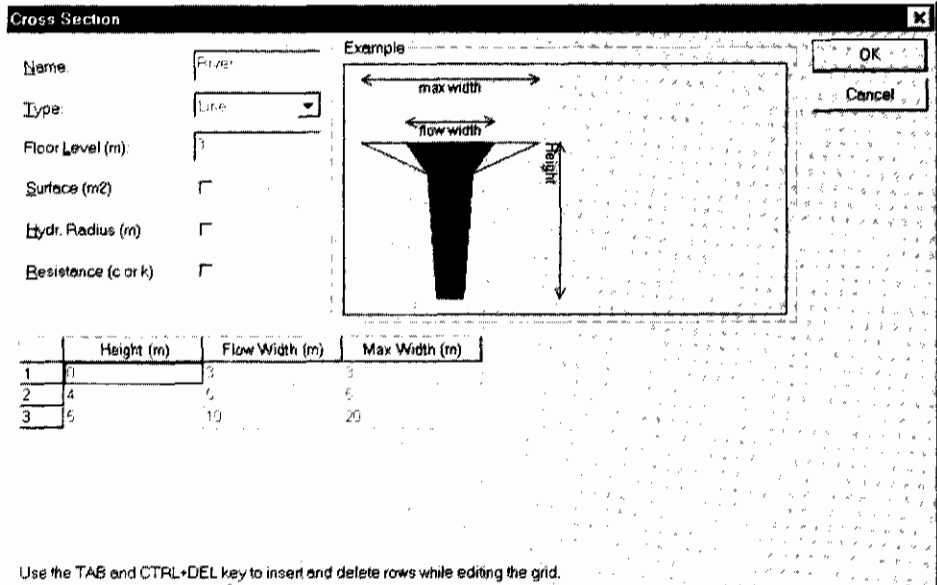


 = Object properties

Cross Sectional data 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 context-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.

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.

= *Weir*

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

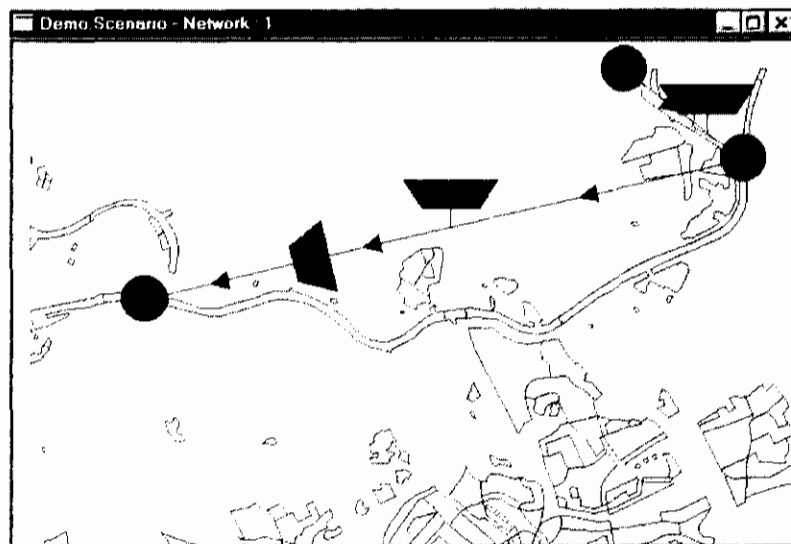
Other structures:

= *Siphon*

= *Culvert*

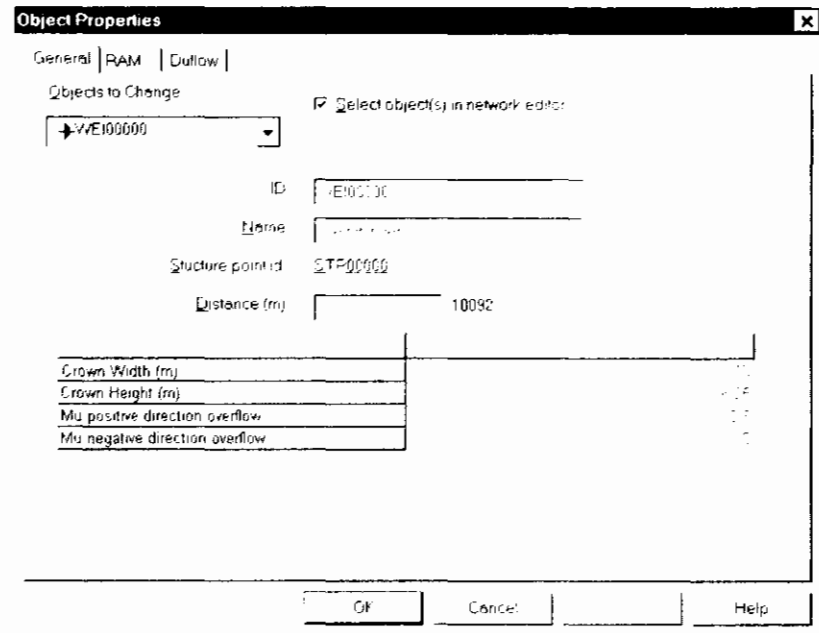
= *Pump*

= *General structure*



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

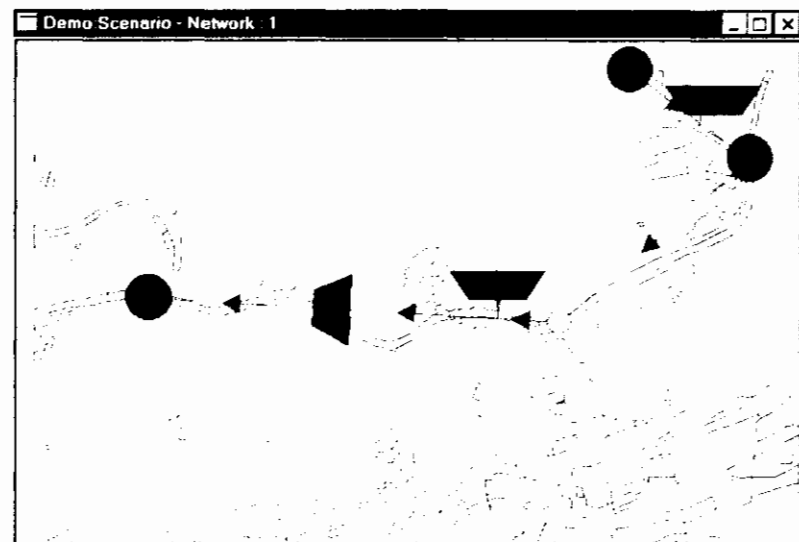
Click the right mouse button on the weir to choose the weir properties as follows:




- o = 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, Structures, Schematization points and Calculation points. DufLOW generates Calculation points when the length of a section exceeds the defined maximum length, i.e. the maximum space step. This 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, add a Schematization point to a section first. Then select the Schematization point and click on the right mouse button and select the option Bending point from the context menu. By dragging the Bending point to the desired position on the waterway the section will bend and more or less 'follow' the waterway.



 = Discharge point

By adding a Discharge point at Schematization points you can define a time series of discharged water or wasted load or concentration.

2.3 Flow Model

To turn a network schematization in a flow model only the following three steps has to be taken;

- Define Initial Conditions
- Define Boundary Conditions
- Configure the calculation

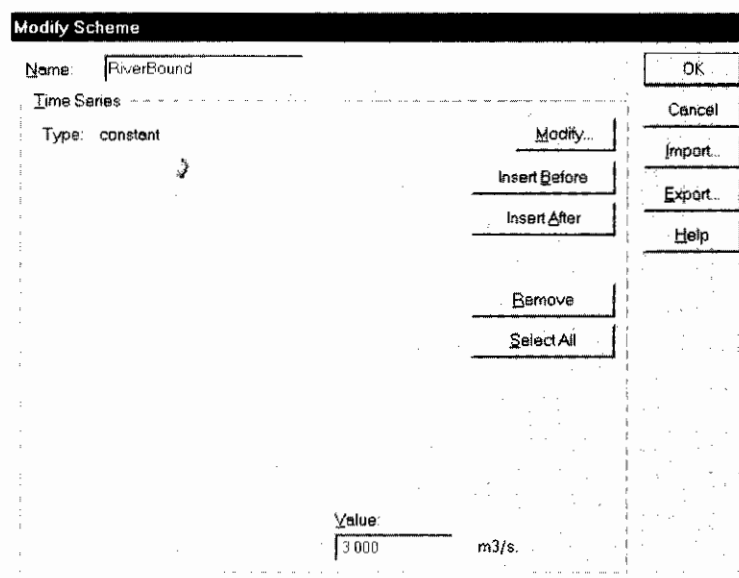
2.3.1 Initial Conditions

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 discharge of 3 m³/s and a initial level of 6 meters (above the reference level). Use the **Set Column...** button. Choose the column Discharge or Level and enter the appropriate value.

2.3.2 Boundary Conditions

In this network a Boundary Condition at the upstream boundary of the water system, the node at the right-handed upper side of the Network, should be defined. 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 a Boundary Scheme should be defined.

To add a *Q-Add Scheme* click on the ... button behind the text box. Then click on the **Add...** button. The following scheme is configured:

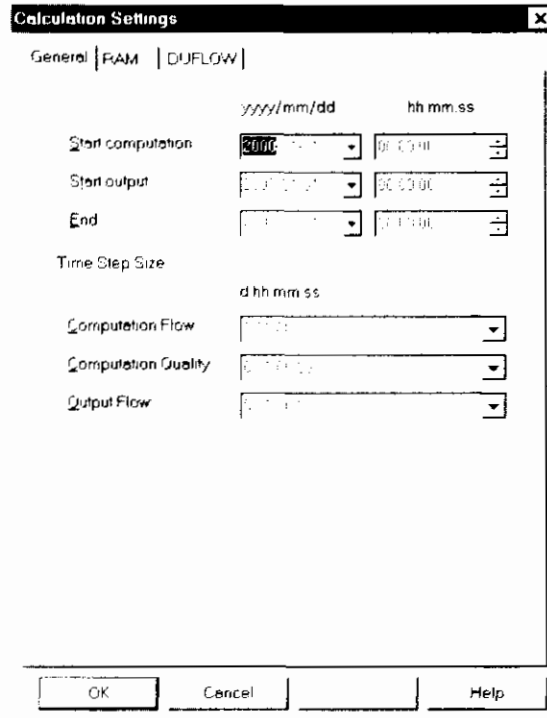


Click **OK** and **OK** and the Q-Add Scheme is now connected to the first Node. Repeat these actions to define a constant Level of 6 metres as a Boundary Condition on the other end of the Network.

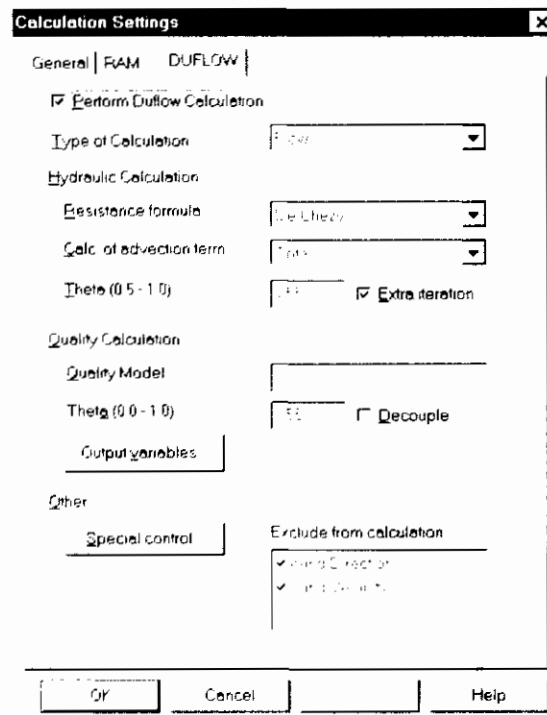
Nodes on which Boundary Conditions are defined have a brighter color than other nodes.

2.3.3 Configure and Start the Calculation


Before starting the calculation check the input in the *Calculation Settings* dialog box. This box is activated by double clicking on *Calculation Settings* in the Scenario manager. On the tab General the calculation period and time step for flow, quality and output can be set. Enter the following values:



The tab DufLOW allows you to set the DufLOW specific calculation options.



The type of calculation can be chosen here. Choose a **Flow** calculation to check if the Network – the Flow model - has been designed correctly. When the flow calculation is verified a quality model can be added. The details for the

 = Calculate


Hydraulic and Quality calculation are set in this dialog box. 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).

The calculation is activated by choosing the *Update All* option from the *Calculation Menu* or F5. The *Output* window shows the initialisation of the calculation. It may be something like:

```
Starting network consistency check...
Check completed.
Starting DufLOW conversion...
DufLOW conversion completed.
Writing project file C:\WinDufLOW\Projects\Demo\Scenario\scenario.duf.
DufLOW conversion completed.
Writing control file C:\WinDufLOW\Projects\Demo\Scenario\scenario.CTR.
Writing network file C:\WinDufLOW\Projects\Demo\Scenario\scenario.NET.
Writing boundary flow file C:\WinDufLOW\Projects\Demo\Scenario\scenario.BND.
Writing initial flow file C:\WinDufLOW\Projects\Demo\Scenario\scenario.BEG.
Writing conversion id's file C:\WinDufLOW\Projects\Demo\Scenario\scenario.sid.
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

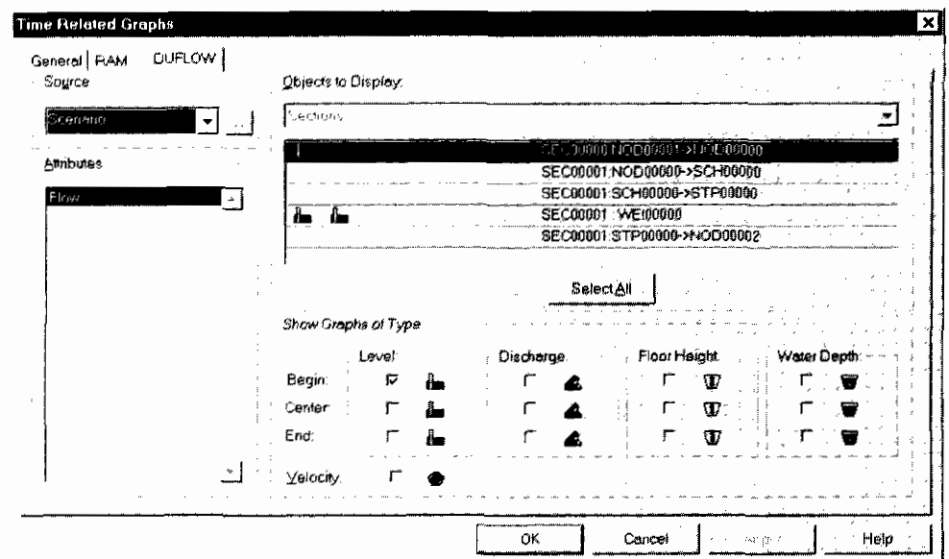
You can show (or hide) the Output window by choosing the option *Output* in the *View* menu.

2.4 Display the Results

Results can be displayed in three different ways:

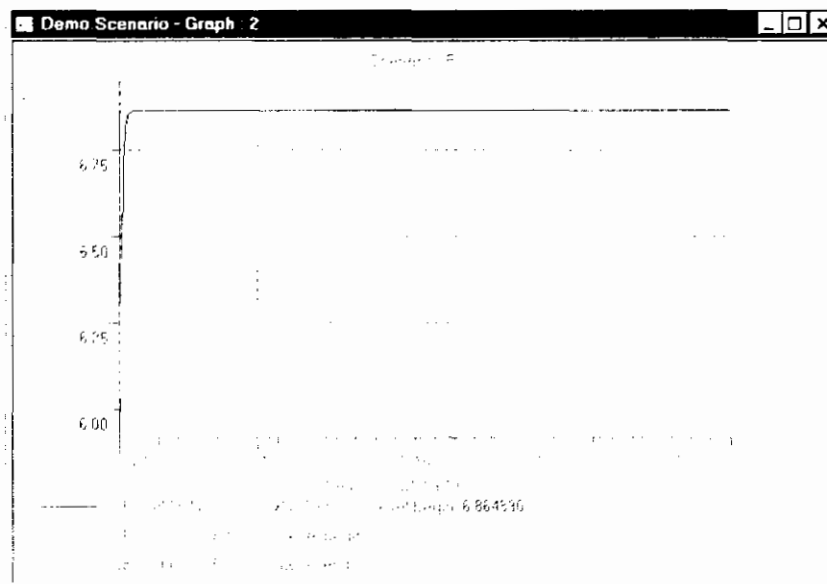
- A Time Related Graph,
- A Space Related Graph,
- As Text in a table as a function of time,
- In the Network window in Presentation mode.

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.



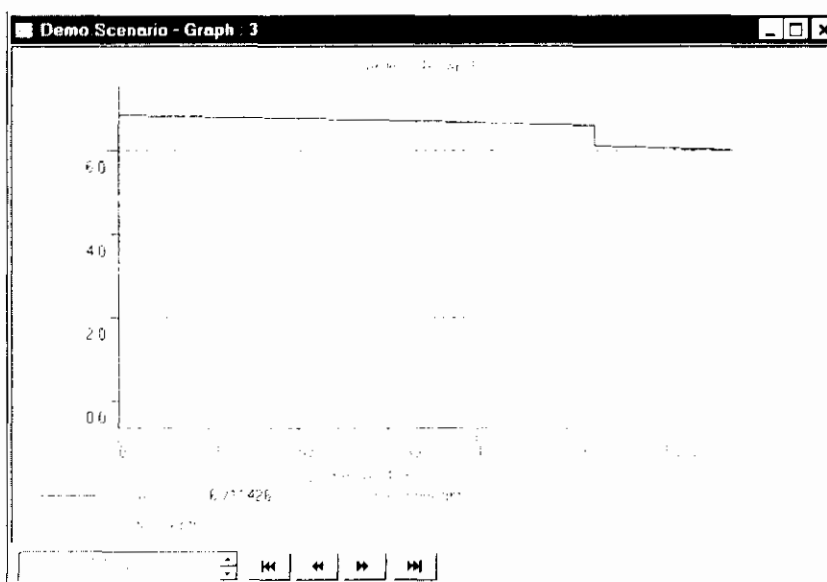
Use **Show Graphs of Type** to choose the type of graph (Level, Discharge or Velocity) of the selected objects in the **Objects to Display** list. After a selection is made, a picture representing the data type is displayed in the row(s) of the selected objects. Selection of the data type to be displayed 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 make a Quality Model out of an existing Flow model, the following actions need to be carried out:

- Define Quality Description file.
- Define Initial Conditions for Quality,
- Define Boundary Conditions for Quality,
- Define External Variables,
- Configure the Calculation.

2.5.1 Define the Quality Description File

To add a Quality Model Description file to the Project enter the name of the *Quality Model description* file without the extension (*.MOD) 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 COUPSE FEBRUARY 1998 */
/* SIMPLE TRACEMODEL */
/* HINNE PELTUMA 02-01-1998 */

WATER TRAC [10.000] mg/l ;TRACER
PAPM Ktrac [0.0100] 1/day ;DECOMPOSITION RATE TRAC
{
K1 (TRAC)=-Ktrac;
}
```

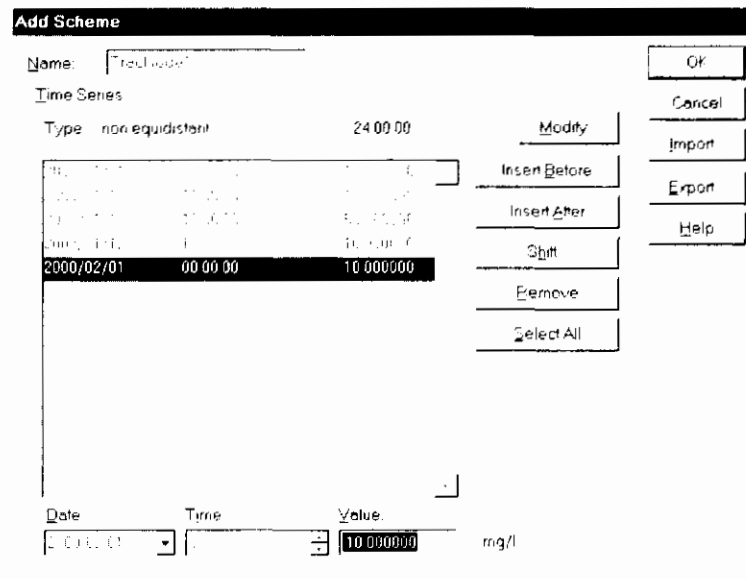
You can enter this description in the *Quality Model description* file by choosing the *Quality Model - Edit* command from the *Scenario* menu. If this definition is inserted correctly - do not forget the blank line at the end - it can be compiled by choosing the *Quality Model Compile* command from 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 Boundary Conditions

The node at the right-handed upper side of the network must also have a Quality boundary condition. Choose the *Properties* dialog box of that node. Choose **Boundary Conditions...** on the tab General. 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 time series:

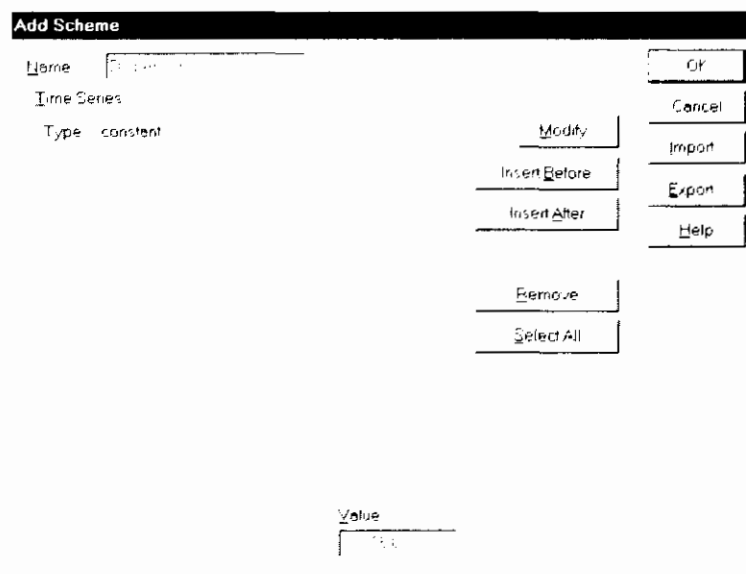


Repeat these actions to define a constant concentration of 10 mg/l as a boundary condition on the other end of the Network. A quality boundary condition is only valid for the incoming water!

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.

2.5.4 External Variables

Dispersion is an external variable, which has to be defined in every Quality Model. An external variable can be added by double clicking 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).



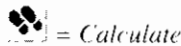
After creating schemes for External Variables you need to connect an External Variables scheme to all Nodes, Schematization points and Structures. In this example the scheme **RiverDispersion** will be used for every object. Choose *Connect to all objects* from the context menu in the Scenario Manager on External Variables. Use the **Arrow** button behind the External Variable 'd' - which appears by selecting the input field - to select the **RiverDispersion** scheme.

In this case a constant value for the dispersion coefficient is used. It is also possible to let DufLOW calculate the dispersion coefficient using the properties of the flow ($D=D_0 + \alpha_v f(\text{flow})$). For technical details please refer to the DufLOW Reference Manual.

2.5.5 Configure and Start the Calculation

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.



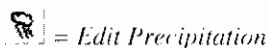
The calculation is activated by choosing the *Update All* option from the *Calculation Menu* (or the *Calculate* toolbar button or the *Calculate* option from the Scenario Context menu). The *Output* window and the Status bar will show the progress of the calculation.

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:

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, 2000 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** field where a value for the Precipitation in mm/day can be entered.

Enter the values as shown below:

Precipitation


Time Series

Type: non equidistant 2400.00

Date	Time	Value
2000/01/01	00:00:00	0
2000/01/02	00:00:00	0
2000/01/03	00:00:00	0
2000/01/04	00:00:00	0
2000/01/05	00:00:00	0
2000/01/06	00:00:00	0
2000/01/07	00:00:00	0
2000/01/08	00:00:00	0
2000/01/09	00:00:00	0
2000/01/10	00:00:00	0
2000/01/11	00:00:00	0
2000/01/12	00:00:00	0
2000/01/13	00:00:00	0
2000/01/14	00:00:00	0
2000/01/15	00:00:00	0
2000/01/16	00:00:00	0
2000/01/17	00:00:00	0
2000/01/18	00:00:00	0
2000/01/19	00:00:00	0
2000/01/20	00:00:00	0
2000/01/21	00:00:00	0
2000/01/22	00:00:00	0
2000/01/23	00:00:00	0
2000/01/24	00:00:00	0
2000/01/25	00:00:00	0
2000/01/26	00:00:00	0
2000/01/27	00:00:00	0
2000/01/28	00:00:00	0
2000/01/29	00:00:00	0
2000/01/30	00:00:00	0
2000/01/31	00:00:00	0
2000/02/01	00:00:00	0

Buttons: Modify, Insert Before, Insert After, Shift, Remove, Select All

Summary: Date: 2000/01/01, Time: 00:00:00, Value: 0 mm/day

 = Edit Evaporation

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

Evaporation

Time Series

Type: non equidistant 2400.00


Date	Time	Value
2000/01/01	00:00:00	0
2000/01/02	00:00:00	0
2000/01/03	00:00:00	0
2000/01/04	00:00:00	0
2000/01/10	00:00:00	0.80000000
2000/01/11	00:00:00	0
2000/01/12	00:00:00	0
2000/01/13	00:00:00	0
2000/01/14	00:00:00	0
2000/01/15	00:00:00	0
2000/01/16	00:00:00	0
2000/01/17	00:00:00	0
2000/01/18	00:00:00	0
2000/01/19	00:00:00	0
2000/01/20	00:00:00	0
2000/01/21	00:00:00	0
2000/01/22	00:00:00	0
2000/01/23	00:00:00	0
2000/01/24	00:00:00	0
2000/01/25	00:00:00	0
2000/01/26	00:00:00	0
2000/01/27	00:00:00	0
2000/01/28	00:00:00	0
2000/01/29	00:00:00	0
2000/01/30	00:00:00	0
2000/01/31	00:00:00	0

Buttons: Modify, Insert Before, Insert After, Shift, Remove, Select All

Summary: Date: 2000/01/01, Time: 00:00:00, Value: 0.80000000 mm/day

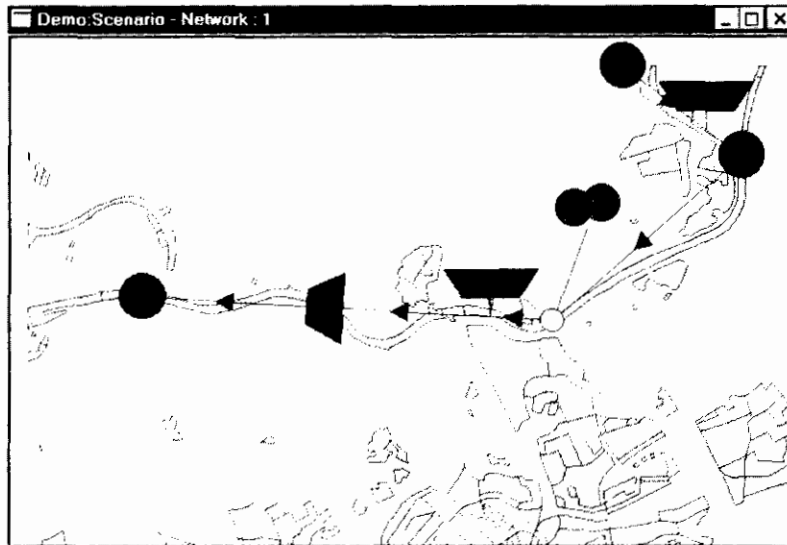
Note: Because the date and time of the time series need to be listed in an increasing order, the final date must first be modified before altering the second date to 2000/01/04. If it is done in a different order, an error message will appear.

2.6.2 Configure the Area

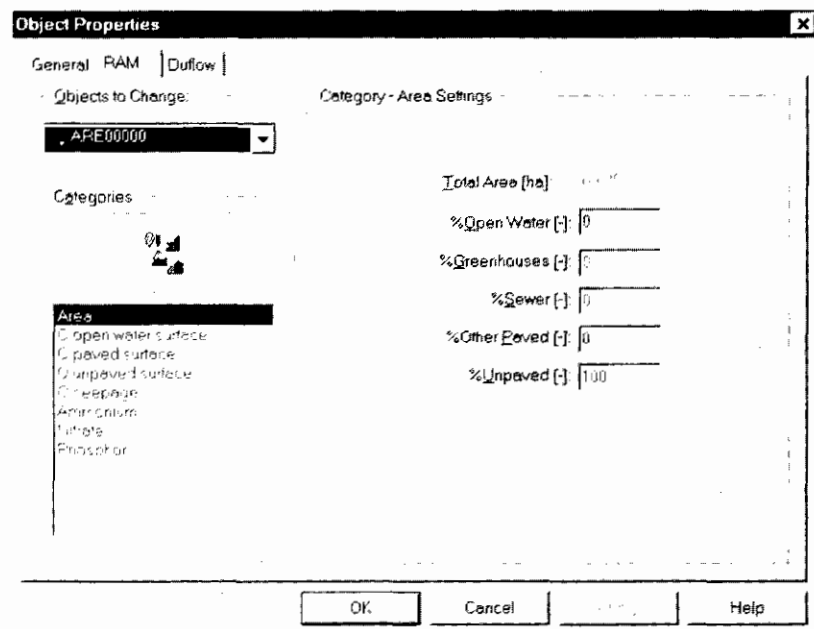
 = Area point

In order to calculate the runoff and the loads to a schematization point in the network, RAM needs to know the properties of the area, around the schematization point, 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.

After connecting an area to a schematization point, it can be moved – by dragging it - away from the schematization point to a 'free' part in the Network window.



To enter the properties of the Area, double-click 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 ($1e+8 \text{ m}^2$). Select the RAM tab to insert the RAM-specific data.



The amount of data per Area is split into logical categories. A category 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:

Unpaved Surface Settings

Surface Type: [OK] [Cancel] [Help] [Advanced]

General Attributes

Attribute	Value
Imax [mm/day]	
f [-]	
F0 [mm]	
F2 [mm]	
F4 2 [mm]	
Phi0 [mm]	
LB0 [mm]	
n [-]	
BLmin [mm]	
Ppermax [mm/day]	
Cmax [mm/day]	
Ksurface [day]	
Kquick [day]	
Kslow [day]	
Bslow [-]	

Scenario: 2 Nest-Cascades

Number of Reservoirs:

Slow: Quick:

Nest-Cascade / Kroyenhoff van de Leur

Number of Reservoirs:

Slow (N): Quick (N):


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 category *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 that have a similar appearance as the *Precipitation* and *Evaporation* dialog box.

2.6.3 Configure and Start the Calculation

Before starting the calculation check the input in the *Calculation Settings* dialog box. This box is activated by the double clicking on the *Calculation Settings* in the Scenario manager. Enter as calculation period the same period as used in the time series for the *Precipitation* and the *Evaporation* (from 1 to 10 January 2000).

On the RAM tab choose the option *Perform RAM Calculation*. Uncheck the option *Perform Dufflow Calculation* on the Dufflow tab.

 = Calculate

The calculation is activated by choosing the *Update All* option from the *Calculation Menu* or F5.

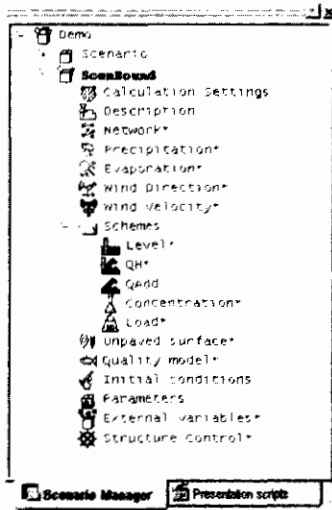
After the calculation, RAM has generated a boundary condition for the additional discharge on the schematization point to which the Area is attached. To show these boundary condition double-click on the Area in the Network window. DMS will open the *Object Properties* dialog box. Click on the **Boundary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

Choose **Modify...** to display the time series that represents the boundary condition.

When a DufLOW calculation is performed again the results of the flow computation will differ from the first computation. In the first DufLOW computation no Precipitation was taken into account.

A DufLOW calculation can be performed automatically after a RAM calculation by checking the option *Perform DufLOW Calculation* (Calculation Settings - DufLOW tab).

2.7 Scenario Manager



A Scenario contains the input data of the model. The input data of a model are divided into several subjects. These subjects are visible in the Scenario Manager. Double clicking on the subject in the Scenario Manager will open a related window or dialog box. Clicking with the right mouse button on the subject in the Scenario Manager will open the context menu. The scenario, which is displayed in a bold font, is the so-called active scenario. Commands given by menu choices or toolbars will always be executed for the active scenario.

With the Scenario Manager the user also can define more scenarios in the same project. Other scenarios can be defined when the user wants to calculate the effect of changes in the base scenario.

By adjusting the *Scenario Properties*, the user can easily combine input data from different scenarios. If in the Scenario Manager the subject is marked with an asterisk, this means that these data are used from another scenario. The subjects in the base scenario are of course never marked.

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. In case of a new scenario – second, third etc. – the user can choose for each subject of that scenario to use the data from another scenario (reference) or to define a local copy and use this data (own data). The default value for the source of a subject in a new scenario is always set on a reference to the base scenario.

New Scenario

In this case we will analyse the effect on the results when using other **Boundary Conditions**. First create a new scenario by opening the context menu after selection of the Project **Demo** in the Scenario Manager, choose *New Scenario*. Name the new scenario **ScenBound**. The new scenario shares its data with the base scenario. To use other boundary conditions in the second scenario do the following;

Scenario Properties

Choose *Scenario Properties* from the context menu after the selection of the second scenario **ScenBound** in the Scenario Manager. DMS will open the *Scenario Properties dialog box*. Change the source of the subject *ObjectData* into 'Own data', change also the subject *Q-add* into 'Own data' (tab General). In the Scenario Manager disappears the asterisk behind *Qadd* (schemes) of scenario **ScenBound**.

Changing values

Double-click on the subject *Q-Add* (scheme) of scenario **ScenBound** in the Scenario Manager. Select the scheme **RiverBound** and change the constant value to 6 m³/day.

Tip

There is an alternative way to calculate a new scenario with other Boundary Conditions. Take the following actions:

1. Create a new boundary scheme **RiverBound6** for *Q-add* (6 m³/day) in the Base scenario **Scenario**.
 2. Create a new scenario **ScenBound2**.
 3. Change in the *Scenario Properties dialog* the source of the *Object Data* into 'Own data'.
 4. Open the Network window of scenario **ScenBound2**, select the boundary node and connect the *Q-add* scheme **RiverBound6** to that node (instead of **Riverbound**)
-

Calculation

Calculate the scenario **ScenBound** by giving the *Calculate* command in the context menu after selection of the scenario **ScenBound** in the Scenario Manager.

Results

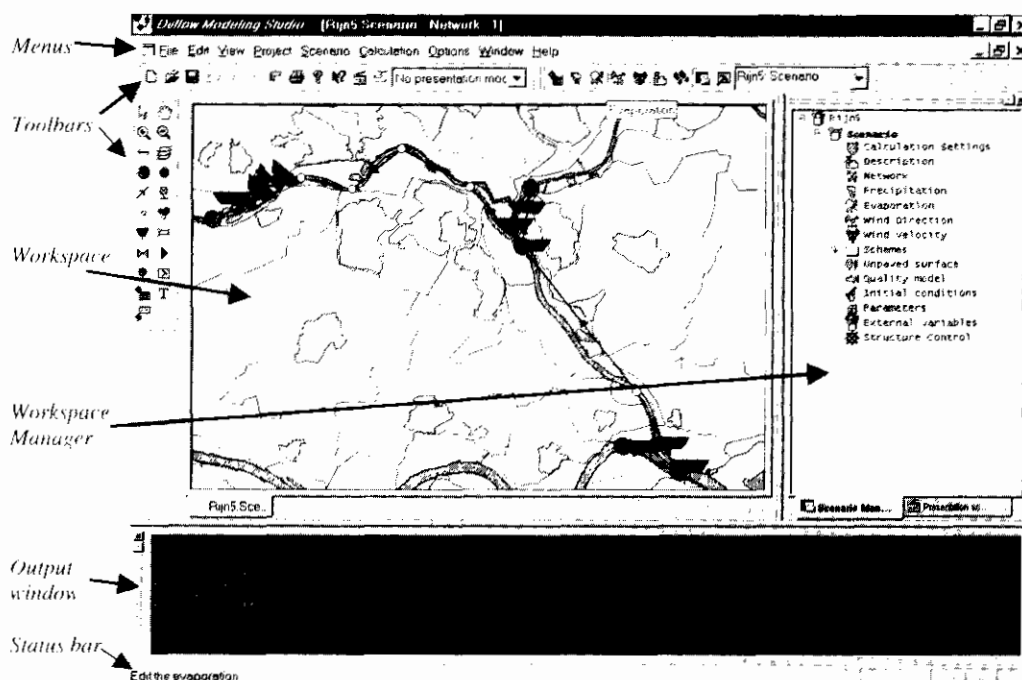
Display the results of both scenarios in one Time Graph window. Open a Network window, select e.g. the weir and open the context menu. Choose *Duflow - New Time Graph window*. DMS will open the *Time Related Graphs dialog box* (the weir is the only available 'section'). Select the **Level Begin** and **Level End** for the source **Scenario** and also for the source **ScenBound**. After choosing **Ok** DMS will open a Time Related Graph with 4 lines.

3. User Interface

3.1 User Interface Components

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

- Menu bar
- Toolbars
- Status bar
- Workspace with the Network window and Results windows
- Workspace Manager window (including the Scenario Manager)
- Output window



In DMS commands can be given at five different ways;

- By making a choices in the menu bar .

- By making choices in the context menu. The context menu appears on the screen by clicking on the right mouse button. The contents of the menu depends on the place where and on the selection which is made before the mouse button is pressed.
- By double-clicking on the left mouse button on a selected object or subject.
- By clicking on toolbar icons
- By using keyboard keys

Note that menu bar, toolbar and key commands are always executed for the Active Scenario. Use the Set as Active Scenario command to change the Active Scenario (see chapter 6 Scenario Manager).

3.2 Menu Bar

The DMS Menu bar, contains the following menus

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

Note that if the Menu bar is used to give commands, these commands are always executed for the Active Scenario. Use the Set as Active Scenario command to change the Active Scenario (see chapter 6 Scenario Manager).

If other applications are often used in combination with DMS, the user can add these tools to the View menu by using the Customize Toolbars, Menus and Windows command.

3.2.1 File Menu

The File menu offers the following commands:

New...	Create a new set of input- and output-files (a new project).
Open...	Open an existing project file.
Close	Close an open project.
Save	Save a project file using the same file name.
Import...	Import existing DufLOW project files made in a DOS-version.
Print...	Print the contents of the active view.
Print Preview	Display the view contents on the screen, as it would appear printed.

Print Setup...	Select a printer and printer connection.
Recently opened Files (1-6)	Open the selected project from the list with the most recently opened projects.
Exit	Exit the DufLOW Modelling Studio.

3.2.2 Edit Menu

The Edit menu offers the following commands:

Undo	Undo the last action (not all actions can be undone).
Cut	Cut the selection.
Copy	Copy the selection.
Paste	Paste the selection.
Objects ► Properties... Select...	Edit the properties of all network objects. Checks the nodes for selection.
Graphs/Table...	Set display options per node for Graph and Table Windows.
Colors...	Configure the colors of the Graph Windows.
Window properties	Set the display properties of the Network Window or the Graph window.
Presentation Mode	Set the script for the presentation mode.
Presentation Scripts...	Edit all presentation scripts schemes.
Editable	Allow or prohibit changes in the Network Window.

3.2.3 View Menu

The View menu offers the following commands:

Toolbar	Show or hide toolbars.
Status Bar	Show or hide the Status bar.
Workbook	Show windows as worksheets in a workbook or as normal windows.
Workspace Manager	Show or hide the Workspace Manager Window (including the Scenario Manager).
Output	Show or hide the Output Window.
Full Screen	Maximize the active Workspace window to screen size.
New Text Window...	Open a new Text output window
New Time Graph Window...	Open a new Time Related output window
New Space Graph Window...	Open a new Graph Related output window
Open Network Window	Open a new Network window

3.2.4 Project Menu

The Project menu offers the following commands:

Properties...	Set the properties of the project.
----------------------	------------------------------------

3.2.5 Scenario Menu

The Scenario menu offers the following commands:

Calculation Settings...		Set the data controlling the calculation.
Description...		Edit the description of the scenario.
Properties...		Set the properties of the scenario.
Delete		Delete the scenario.
Precipitation...		Edit precipitation parameters.
Evaporation...		Edit evaporation parameters.
Wind direction...		Edit wind direction parameters.
Wind velocity...		Edit wind velocity parameters.
Schemes ▶ Level...		Edit all level boundary schemes.
QH...		Edit all QH-relation boundary schemes.
Q-Add...		Edit all Q-Add boundary schemes.
Concentration...		Edit all concentration boundary schemes.
Load...		Edit all load boundary schemes.
Import time series ...		Read all time series from an ASCII-file.
Export time series...		Write all time series to an ASCII-file.
Unpaved schemes...		Edit the unpaved schemes...
Quality model	Edit	Edit the Quality model.
▶	Compile	Compile the Quality model.
Initial conditions...		Set the initial conditions for the scenario.
Parameters...		Set the parameters for the Quality model.
External Variables...		Set the external variables.
Structure Control...		Set the structure control for the scenario.

3.2.6 Calculation Menu

The Calculation menu offers the following commands:

Update All	Update the calculation. This command executes the following three commands: Convert Network, Write DufLOW files, Run DufLOW model.
Convert Network	Convert the DMS network into a DufLOW network.
Write DufLOW files	Write the DufLOW files.
Run DufLOW model	Run the DufLOW model using the DufLOW files.
Cleanup Network	Clean the Network window by removing the Calculations points and re-color the objects.
Reset Errors	Reset the errors in the Network window. The red-colored objects will receive their original color.
Terminate Calculation	Terminate the calculation or compilation.

3.2.7 Options Menu

The Options menu offers the following commands:

Customize...	Configures the DMS toolbars, menus and windows.
Settings...	Sets the directories for the presentation.

scripts and other program settings.

3.2.8 Window Menu

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

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.
Windows	Customizes the appearance of the windows in the Workspace.

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 six toolbars. The Standard toolbar, the Scenario toolbar, the Window toolbar, the Time Control toolbar and the DufLOW toolbar are displayed across the top of the DMS-window, below the Menu bar. The Palette toolbar is displayed next to the workspace.

To hide or display a toolbar, choose **Toolbar** from the **View** menu, i.e. the **Display or hide Toolbar** command. To customize a toolbar, choose **Customize** from the **Options** menu, i.e. the **Customize Toolbars, Menus and Windows** command.

Note that if the **Menu bar** is used to give commands, these commands are always executed for the **Active Scenario**. Use the **Set as Active Scenario** command to change the **Active Scenario** (see chapter 6 Scenario Manager).

3.3.1 Display or Hide Toolbar

Use the **Display or hide Toolbar** command to display or hide a toolbar. DMS will open the **Toolbars** dialog box. DMS displays a toolbar if the checkbox next to this toolbar is marked.













Command:

Menu bar: **View - Toolbar**

3.3.2 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.
-  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.
-  Edit the Presentation Script of the Network window.


Change the Presentation Mode or Script of the active Network window.


3.3.3 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 Workspace Manager window (including the Scenario Manager).
-  Show or hide the Output window.
-  Edit the level schemes.
-  Edit the QH-relation schemes.
-  Edit the Q-Add schemes.
-  Edit the concentration schemes.

 Edit the load schemes.


 Edit the calculation settings.


Demo: Scenario  Select the active scenario.


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.

 Show or hide the text – ID's – of network objects.








 Show or hide datatips of network objects.

NOD00002  Locate object in the Network window.

3.3.5 Window Toolbar

The Window toolbar offers the following commands:








Click To

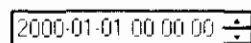
-  Arrange windows in an overlapped fashion.
-  Arrange windows in non-overlapped tiles - horizontally.
-  Arrange windows in non-overlapped tiles - vertically.
-  Open a new Text window.
-  Open a new Time Related Graph window.
-  Open a new Space Related Graph window.
-  Open a Network window.

3.3.6 Time Control Toolbar

The Time Control toolbar offers the following commands:

Click To

-  Jump to the first time step.
-  Jump to the previous time step.
-  Jump to the next time step.
-  Jump to the last time step.
-  Start the timer.
-  Stop the timer.
-  Configure the timer.








Presents the current time of the displayed results. The results will be adjusted if the user changes the time.

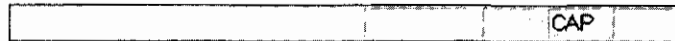
3.3.7 Duflow Toolbar

The Duflow toolbar offers the following commands:

Click To

-  Edit the initial conditions.
-  Edit the Quality model.
-  Edit the external variables of the Quality model.
-  Edit the parameters of the Quality model.
-  Edit the structure control data.

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, i.e. the Display or hide Status bar command.

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 also in the left area the position of the cursor in the network, while moving the cursor through the window. When editing the Quality model the right area displays the position of the cursor.

The right areas of the Status bar indicate the position of the cursor in the Quality model and also 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.

3.4.1 Display or Hide Status Bar

Use this 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 bar: View - Status Bar

3.5 Workspace

The Workspace can contain the Network window and Results 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:

Toolbar	Menu	Command
	View	Open Network window
	View	Open new Text window
	View	Open new Time Related Graph window
	View	Open new Space Related Graph window
	Scenario	Edit Quality Model
	Standard	Edit the Presentation Script of the Network window.

To activate a window and bring it to the front use the command *Window 1, 2, ...* in the *Window* menu, i.e. the *Activate Window* command. 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 open windows use the *Workbook* command.

Use the *Splitter* to modify the size of the *Workspace* window.

To modify the size of the windows in the *Workspace* window you can use the common *Windows*-buttons. These buttons for *Minimize Window*, *Restore Window*, *Maximize Window* and *Close Window* can be found on right side of the window or on the right side of the *Menu bar* when the window is maximized.

Tip By opening an existing project, DMS can open automatically the windows that were opened in a previous session. Use the *Program Settings* command to mark the option *Reload Windows* in the *Program Settings* dialog box.

To modify the appearance of the *Workspace* window(s) DMS offers the following commands:

- Full Screen
- Workbook
- Arrange windows
- Tile windows
- Arrange icons
- Activate Windows
- Windows

3.5.1 Full Screen

Use this command to maximize the active *Workspace* window to screen size. Press the **Escape** button to restore the window to its original size.

Command:

Menu bar: View - Full Screen

Keys: Alt-Enter

3.5.2 Workbook

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

Command:

Menu bar: View - Workbook...

3.5.3 Arrange Windows

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

Command:

Menu bar: Window - Cascade

Toolbar: 

3.5.4 Tile Windows

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

Command:

Menu bar: Window - Tile

Toolbar: 

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

Toolbar: 

3.5.5 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 window at the bottom of the Workspace, some or all of the icons may not be visible because they will be underneath the active window.

Command:

Menu bar: Window - Arrange Icons

3.5.6 Activate Window

DMS displays a list of open 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 bar: Window - Windows 1,2...

3.5.7 Windows

Use this command to customize the appearance of the Windows in the Workspace. DMS opens the Windows dialog box.

Command:

Menu bar: Window - Windows

3.6 Workspace Manager window

The Workspace Manager window consists of two tabs.

On the Scenario Manager tab a project-tree for all open Projects is displayed. 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 change the font in the Scenario Manager, click on the right mouse button outside the project-tree.

On the Presentation Mode tab all available Presentation scripts are presented. To modify a Presentation Script, double click on the left mouse button on a script. DMS will open a Window in the Workspace with the contents of the script.

To display or hide the Workspace Manager window, use the Workspace Manager command in the View menu, i.e. the Display or hide Workspace Manager window command.

Use the Splitter to modify the size of the Workspace Manager window.

3.6.1 Display or Hide Workspace Manager

Use this command to display or hide the Workspace Manager Window. The Workspace Manager window contains the Scenario Manager, with the model data and one or more Scenario's and an overview of the Presentation Scripts.

Command:

Menu bar: View Workspace Manager

Toolbar: 

Keys: ALT+0

3.7 Output window


The progress of DMS-actions is 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 Display or hide Output command. Use the Splitter to modify the size of the Output window.

3.7.1 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 bar: View Output

Toolbar: 

Keys: ALT+2

3.8 DMS Commands

The following commands can be used in all parts of DMS:

- Undo last action
- Cut, Copy and Paste selection
- Print, Print Preview and Print Setup
- Customize toolbars, menu and windows
- Program settings
- Splitter
- Help and Context Help
- About DMS
- Exit DMS

3.8.1 Undo Last Action

Use this command to undo the last action.

Command:

Menu bar: Edit - Undo

Toolbar: 

Keys: CTRL+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 bar: Edit - Cut

Toolbar: 

Keys: CTRL+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 bar: Edit - Copy


Toolbar: 
Keys: CTRL+C

3.8.4 Paste Selection

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

Command:

Menu bar: Edit - Paste

Toolbar: 


Keys: CTRL+V

3.8.5 Print

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

Command:

Menu bar: 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 bar: 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 bar: File - Print Setup

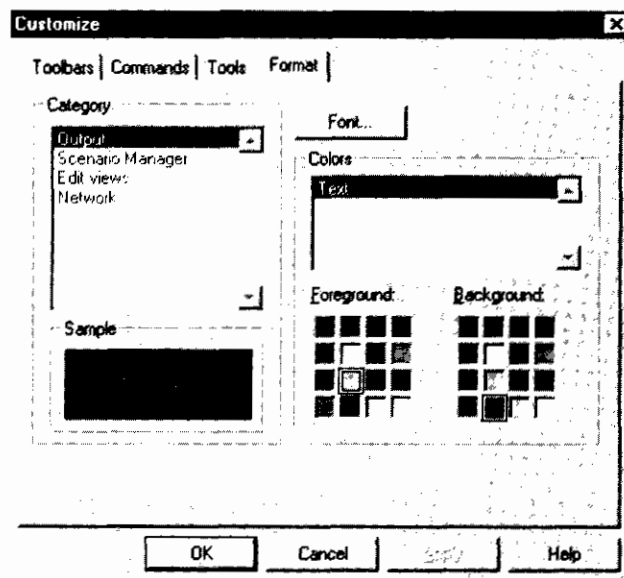
3.8.9 Customize Toolbars, Menu and Windows

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 bar: Options - Customize...

3.8.10 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 can be added to the View menu. This can be done if other applications are often used in combination with DMS.

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

3.8.11 Program Settings

Use the Program 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 bar: Options - Settings...

Related topics:

Program Settings dialog box




3.8.12 Program Settings dialog box

In the Program Settings dialog box the following options can be set:

Presentation Script directories

The directories with Presentation Script files. Presentation Script files have the extension *.PSF. The default Presentation directory is C:\WinDuflow\Presentation. Example scripts are available in this directory.

Using the following buttons can change contents of the directory list.

-  Add a new directory. In the list a new line appears. Use the ... button on the new line to open the Select Directory dialog box.
-  Delete the selected directory.
-  Move to the previous directory.



Move to the next directory.

Reopen window when opening the project

By opening a project, the windows, which were opened the last time this Project was opened, will be reopened automatically.

Reload Projects at startup

By starting DMS, the projects that were opened at the previous session will be reopened automatically.

Always allow jumps in objects property dialog

This option makes it possible in the Object Properties dialog box (General tab) to jump to the related object.


Note that the performance of DMS while changing object properties decreases when this option is chosen.

Related topics:

Program Settings

3.8.13 Splitter

The DMS-window is divided into the Workspace Manger window, the Workspace and the Output window.

Splitter symbol: 

The Splitter influences the space relation between the three parts. 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. Dragging the splitter icon moves the bar.

3.8.14 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 bar: Help - Help Topics

3.8.15 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

3.8.16 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 bar: Help - About DMS...

Toolbar: 

3.8.17 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 Dufrow Internet site.

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

3.8.18 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 bar: File - Exit

Mouse: Click the application's Exit button.

Keys: ALT+F4

4. Project and base Scenario

4.1 Project versus Scenario

In DMS a Duflow model is considered as a Project. To build a model in DMS you have to create a new Project. A Project consists of one or more Scenarios. If a new Project is created, the first Scenario will be created automatically. The first Scenario is the base Scenario. A Scenario contains the input data of the model. The following types of data can be distinguished;

- Description of the scenario.
- Schematization / Network objects.
- Initial Conditions.
- Boundary Conditions, stored in schemes.
- Other conditions and schemes (precipitation, evaporation, wind direction, wind velocity, structure control and unpaved schemes).
- Quality Model. (Quality Model description file, parameters, external variables)
- Calculation Settings.

The Network schematization can be build with the Network Editor. The Scenario Manager supports the user to enter the other data.

With the Scenario Manager the user also can define more scenarios in the same project. Other scenarios can be defined when the user wants to calculate the effect of changes in the base scenario. The Scenario Manager manages all the data and information needed to run the various simulation model scenarios and to store and administrate all scenario's which have been run. 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.

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.

Related topics:

New Project

Open Project

Project Properties

Usage of the Network Editor

Usage of the Scenario Manager

4.1.1 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 bar: Project - Properties...

Context menu: In the Scenario Manager window after the selection of a project - Properties...

4.1.2 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 Project Commands

DMS offers the following commands to add or modify Projects.

- New Project
- Open Project
- Close Project
- Save Project

With the Import Files command Projects or Project files, which were made in Duflow for Dos, can be easily imported in DMS.

DMS offers no command to delete a project. Projects can be deleted by using a file manager program and deleting the directory of the Project and its contents.

The properties of a Project can be set with the Project Properties command.

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 bar: File - New...

Context menu: 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) will 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.

The following options allow you to specify the initial settings of the Network window:

X Co-ordinate	The X co-ordinate of the bottom left-hand corner of the Network window when it is opened for the first time within this project. The unit of the X co-ordinate is metre [m].
Y Co-ordinate	The Y co-ordinate of the bottom left-hand corner of the Network window when it is opened for the first time within this project. The unit of the Y co-ordinate is metre [m].
Numbers of metres per pixel	The scaling of the Network window when it is opened for the first time within this project.

You can open an existing Project File with the Open Project 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:

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

If the project is recently modified, try to use the Recently Opened Projects command.

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

A project can also be opened by double clicking on the *.DMS file in the Explorer.

You can create a new project with the New Project command.

Command:

Menu bar: File - Open...

Toolbar: 

Keys: CTRL+O

Tip	By starting a new session, DMS can open automatically the projects that were opened in a previous session. Use the <i>Program Settings</i> command to mark the option <i>Reload Documents</i> in the Program Settings dialog box. By marking the option <i>Reload Windows</i> in the Program Settings dialog box also the windows of the project will be opened again.
------------	--

4.2.4 Close Project

Use this command to close the Project. DMS suggests that you save changes to your files before you close 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


Command:

Menu bar:	File - Close
Context menu:	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.

Command:

Menu bar:	File - Save
Context menu:	In the Scenario Manager after the selection of a project - Save
Toolbar:	
Keys:	CTRL+S

4.2.6 Import Files

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

To import a complete Dufflow 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:

Name	Extension	Description
Dufflow Projects File	*.PRJ	File that contains a list of the files needed to run the complete Dufflow model.
RAM Projects File	*.RAM	File that contains a list of the files needed to run the complete RAM model.
Boundary Conditions Flow	*.BND	In this file all boundary conditions

File		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 bar: 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.

4.2.7 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 bar: File - Recently Opened Projects 1,2,...

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 Network editor consists of the Network window and the Palette toolbar. The desired network 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. When opened, the Network window appears in the Workspace.

A network can be easily built on a Map layer, reducing the errors in the schematization of a surface water system.

This Network Editor is based on the standard exchange format (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 and sections.

- Nodes are points at which one or more sections arises 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 from the Palette toolbar into the Network window.

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

The length of the sections and the distances of the objects from the begin node - of the section where they are defined on - is automatically calculated by DMS. This calculated lengths and distances are based on the positions of the (begin) nodes and objects in the Network window. By entering a check mark behind the field Distance (Length in case of a section), which is a property of an object, the user can override the calculated value of DMS.

Tip If the calculated section length or object distance is overruled by the user, DMS will mark these objects in the Network window with a thick dark green border.

In DMS nodes are defined at the boundaries of the network and in situations where three or more sections meet. They also can be added to the network to enforce a jump in the bottom level.

A section is defined between two nodes. 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 by changing the field Maximum length of a section. This leads to the fact that after conversion of the network, the DMS section is divided into DufLOW sections of approximately this maximum length. DMS will generate Calculation points for this purpose.

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

In the Network window also calculation results can be presented: e.g. the color of a section can represent a value for the level or discharge at a certain moment. This way of presenting results is called the Presentation Mode.

Related topics:

- Open Network window
- Display layers
- Network Objects
- Network Object commands
- Customizing Network window
- Workspace
- Palette toolbar

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. The Network window always appears in the Workspace.

If the Network window of a project is opened for the first time, the initial position of the left-hand bottom corner and the distance per pixel are as they were defined in the New Project dialog box.

Command:

Menu bar: View - Open Network Window.

Context menu: In the Scenario Manager window after the selection of a scenario – Open Network Window.

Toolbar: 

Related topics:

Usage of the Network Editor

Workspace

5.1.2 Display Layers

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

Command:

Toolbar: 

Only Shape-files can be used as a map layer in DMS. These files are of the type *.SHP. They always come together with a database file (*.DBF) and a index file (*.SHX). Each shape file represents a certain geographic theme. Shape files can be save in a group in a VSF-file.

Tip If you want to use AutoCAD files (*.DXF) as background images, you can easily convert them to Shapefiles with e.g. Arcview. On the Dufrow Internet site you can find a FAQ with a brief description of a proven method.

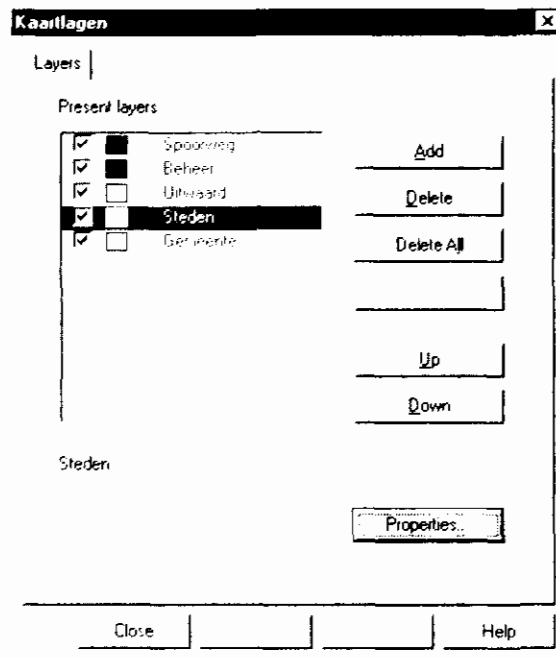
Related topics:

Display Layers dialog box

Project Properties

5.1.3 Display Layers dialog box

The Display Layers dialog box contains a list with the present layers. The order of the layers in this list corresponds 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:

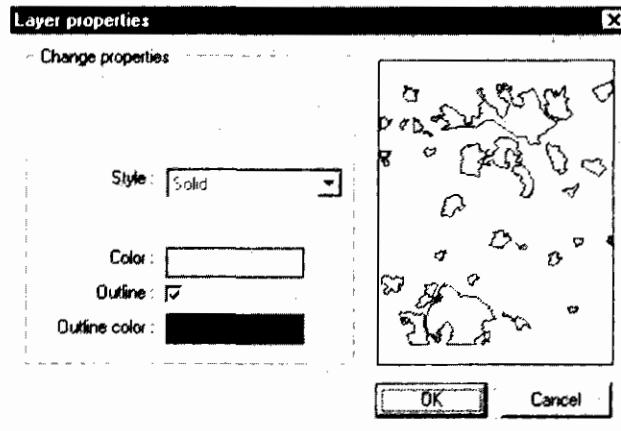
- | | |
|----------------------|---|
| File Name | Type or select the file you want to open. The listbox lists files with the extension you select in the Files of Type combobox. |
| Files of Type | Select the type of file you want to open:
*.SHP is the extension for a Shape file.
*.NB (a database file *.DXF and an index file *.SHX file with the same name must also be available !)
*.VSE 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
- Layers Properties dialog box

5.1.4 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** button 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 layer must be selected in the Display Layers dialog box by using the **CRTL** or **SHIFT** button









Related topics:




Display Layers dialog box

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

The following object can not be added by the user, but can be generated by DMS.

-  Calculation point

Modifying properties of the objects is done in the Object Properties dialog box by using the Objects Properties command.

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-co-ordinate	The X-co-ordinate 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-co-ordinate	The Y-co-ordinate 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]

Sections The list contains all sections that come together at the node. The Direction of the sections has the value 'In' or 'Out', depending on the direction of the section. The Weight represents the initial ratio over the sections with regard to the discharge or load over the node.

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.

External Variables

declared in the Quality Model description file.

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.

If a node should be added to a section of an existing network use the Insert Node command instead of dragging the object Node from the Palette Toolbar. The section on which the command is used will be split into two sections that inherit the properties of the splitted section.

If two sections come together at a node, this node can be removed with the Remove Node and Join Sections command. By using this command the sections that come together at this Node will be joined. Otherwise – with the Remove Object command – two sections without a begin or end node will be created.

Related topics:

Object Properties command

Insert Node

Remove Node and Join Sections

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 [m] based on the length of the section in the Network window. By entering a check mark behind the 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. Warnings will be generated for (part of) sections that are smaller than the minimum length. [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 [m]

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 gray diamonds after the Calculate command is given. The Calculation points will disappear by the Cleanup Network command.

Interpolate Cross Sectional Data

By choosing this option DMS will interpolate the cross sectional data between the Cross Sections, inserted on this section. The cross sectional 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 however the floor level (bottom) is part of the cross sectional data, it will always be interpolated between two Cross Sections.

Wind Conversion factor

Wind conversion coefficient = 10³. 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.

The direction of the section will be used for the calculation of the distances of the objects on that section. The distance is calculated from the begin node of the section. The direction of the section defines the begin node of the section.

If the user defines the direction of a section in the stream direction of the water, the calculated discharge and velocity will be positive, otherwise they will be negative. You can change the direction of a section easily by using the Flip Orientation command.

Related topics:

Object Properties command

Calculation point

Interpolation of Cross Sectional Data

Flip Orientation

5.2.3 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-co-ordinate	The X-co-ordinate 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-co-ordinate	The Y-co-ordinate 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 Cross Section dialog box	

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 ($v=K \cdot R^{2/3} \cdot I^{1/2}$) 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 ($v=K \cdot R^{2/3} \cdot I^{1/2}$) 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.

Related topics:

Object Properties command

Cross Section dialog box

Interpolation of Cross Sectional Data

5.2.4 Cross Section dialog box

Cross Section [X]

Name:

Type:

Floor Level (m):

Surface (m²):

Hydr. Radius (m):

Resistance (c or k):

Example

	Height (m)	Flow Width (m)	Max Width (m)
1	1	5	10
2	2	7.5	15
3	3	10	20

Use the TAB and CTRL+DEL key to insert and delete rows while editing the grid

OK
Cancel

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.	
Floor Level	The level of the lowest point of the Cross Section above the reference level.	[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.	[m ³ /s] or [m ² /s]
	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 ($v = K \cdot R^{2/3} \cdot J^{1/2}$). The value for the Resistance can be inserted for the	

	positive and negative direction of the section.	
Height (Line)	Depth to Floor Level (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]

Related topics:

Cross Section

Interpolation of Cross Sectional Data

5.2.5 Interpolation of Cross Sectional Data

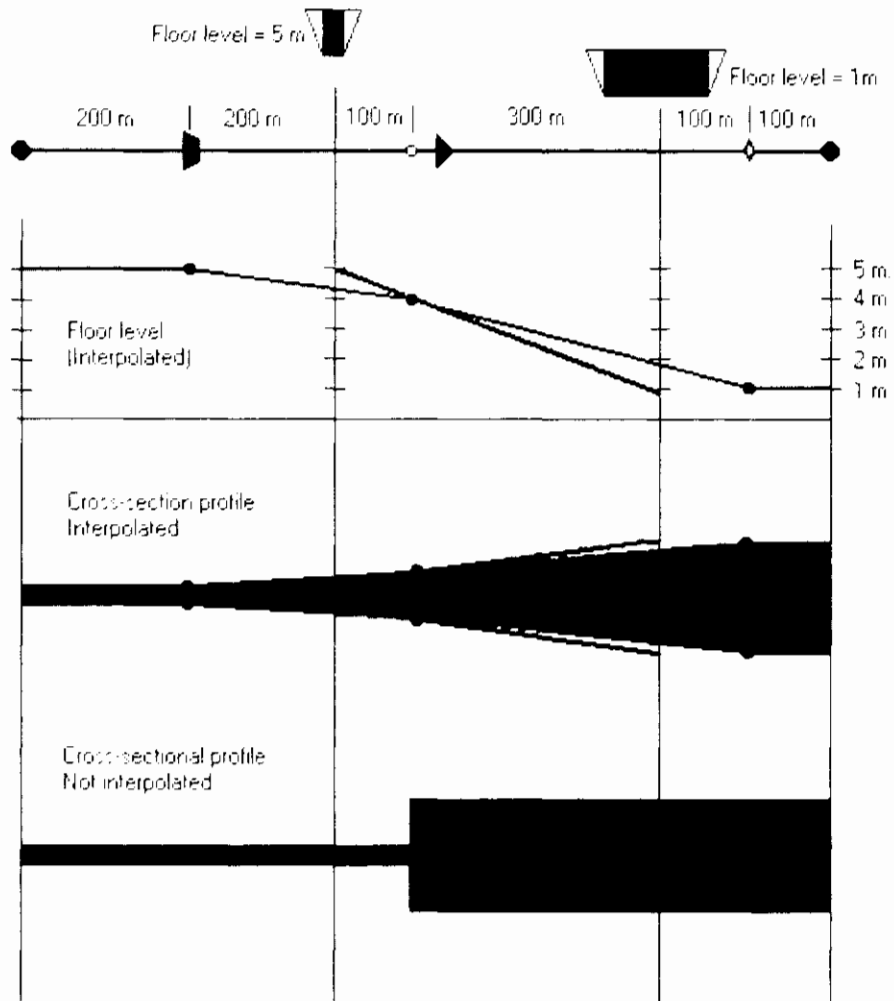
At least one Cross Section must be defined on a section. If more than one Cross Section is defined on a section, DMS will default interpolate the cross sectional profile. The option Interpolate Cross Sectional Data is a property of the section. The Floor level – also a property of a Cross Section scheme – however will always be interpolated, even if the option Interpolate Cross Sectional Data is off. Note that interpolation of the cross sectional profiles will only take place over one section. Interpolation of cross sectional data will never take place between Cross Sections on two different sections.

Interpolation of cross sectional data consists of three parts.

- First the values for Floor Level and the cross sectional profile on the DufLOW points **between two Cross Sections** will be calculated by interpolation (red line in the figures). DufLOW points are nodes, schematization points, structure points – i.e. structures – or calculation points.
- Secondly the DufLOW points **between the begin Node and the first Cross Section** will inherit their cross sectional data from the first Cross Section.
- Third the DufLOW points **between the last Cross Section and the end node** will inherit their cross sectional data from that last Cross Section.

Note that the direction of the section plays an important role in this interpretation.

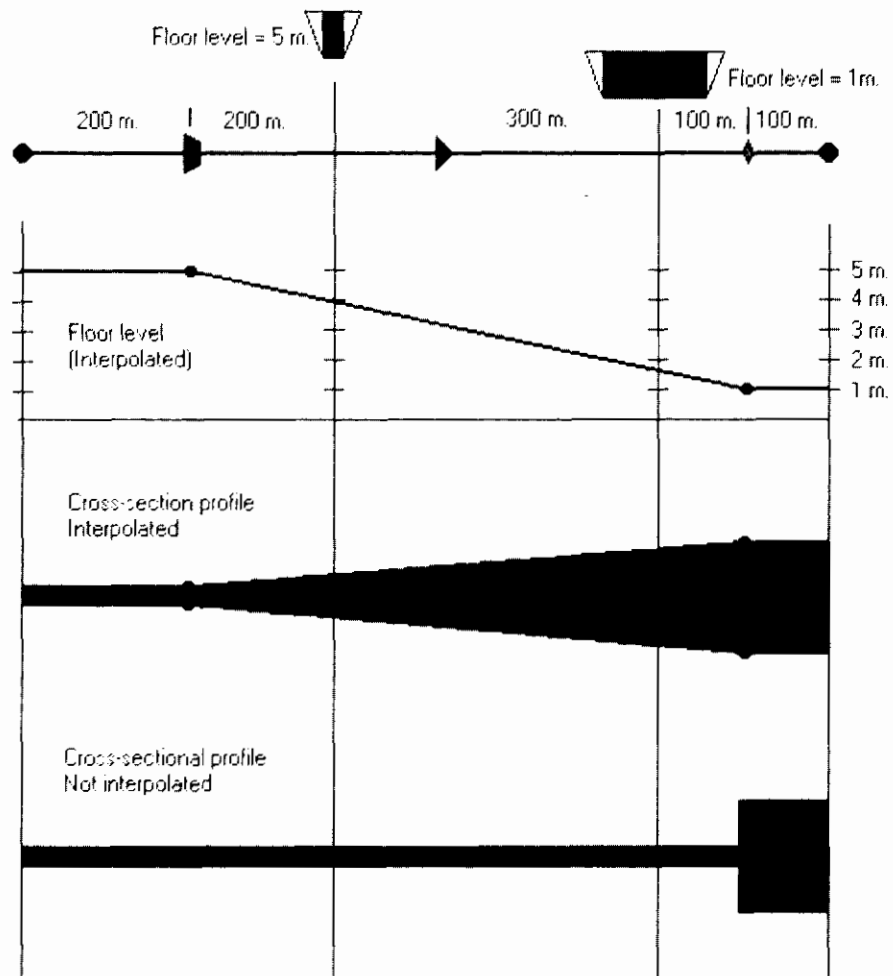
Example 1: DufLOW points between Cross Sections



After defining the cross sectional data on the DufLOW points of a section, the cross sectional data between these DufLOW points can be calculated by interpolation. The results of this interpolation are visible in the figures as a black line for the Floor level (bottom) and the blue area for the Flow-width at a certain depth. During calculation however only the cross sectional data on the DufLOW points will be used.

If the distance between two DufLOW points is smaller than the Minimum Length of the section, than this section will not be a part of the calculation. Therefore also the cross section definition for this (part of a) section will not be taken into account.

Example 2: No Duflow points between Cross Sections



Tip


If the Floor Level (bottom) upstream from a weir differs from the Floor Level downstream, then just add a Node very close to the weir. If the distance between the Node and the weir is less than the Minimal Length of the section, the Floor level will not be interpolated over the weir. Use the Insert Node command to add the Node.

Related topics:

- Cross Section
- Cross Section dialog box
- Section

5.2.6 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-co-ordinate	The X-co-ordinate 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-co-ordinate	The Y-co-ordinate 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

Default a schematization point *only* can be moved along the section. If the schematization point is changed into a Bending point it also can be moved 'outside' the section. The section will get curves. The length of the section is updated automatically. Use Bending points to follow the curves of a river.

Related topics:

Object Properties command

Bending point

5.2.7 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 that 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

Related topics:

Object Properties command

5.2.8 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.

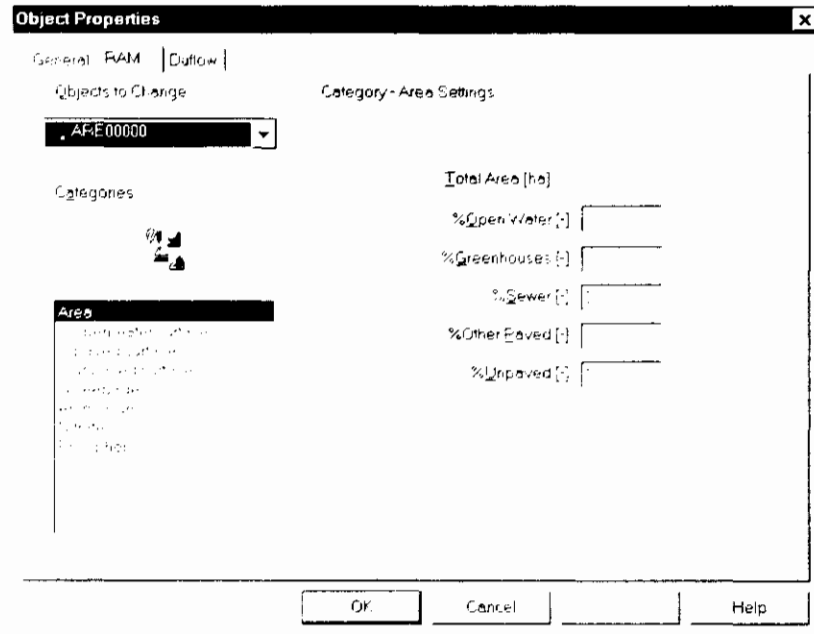
Symbol: 

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. [m²]
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 Water
- Percentage of the total area that consists of surface water. [-]
- % Greenhouses
- Percentage of the area with greenhouses. [-]
- % Sewer
- Percentage paved surface with sewer. [-]
- % Other Paved
- Percentage consisting of other paved surface. [-]
- % Unpaved
- Percentage of the area used as farmland (the precipitation is flowing away slowly). [-]



Open Water surface

- K
- Time constant reservoir [day]
- f
- Crop factor Makkink [-]



Paved surface

- K
- Time constant reservoir [day]
- B_{max}
- Maximum storage in depressions [mm]
- B_{reservoir}
- Storage in reservoirs [mm]
- % Open Surface
- Percentage of the category area that consists of open paved surface. [-]
- P_{max}
- Pump over capacity [mm/day]
- I_{max}
- Infiltration capacity [mm/day]
- I_b
- Maximum infiltration capacity [mm/day]
- I_e
- Minimum infiltration capacity [mm/day]
- K_{decay}
- Time factor for reduction infiltration capacity [1/day]
- K_{restore}
- Time factor for enlarging infiltration capacity [1/day]

Note: For the crop factor Makkink (f) the

open surface value is also used for paved surface.



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.

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.

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.

For technical details please refer to the RAM Reference Manual.

Related topics:

- Object Properties command
- Unpaved Surface Scheme command
- Unpaved Surface Settings dialog box

5.2.9 Unpaved Surface Settings dialog box

Parameter	Value
I_{max} [mm/day]	100
f [-]	0.1
$F0$ [mm]	10
$F2$ [mm]	10
$F4.2$ [mm]	10
Φ_{i0} [mm]	10
L_{B0} [mm]	10
n [-]	0.4
BL_{min} [mm]	10
$P_{perc,max}$ [mm/day]	10
C_{max} [mm/day]	10
$K_{surface}$ [day]	10
K_{quick} [day]	10
K_{slow} [day]	10
B [-]	10

Scenario

Nash-Cascades

Number of Reservoirs:

Slow:

Quick:

Krayenhoff van de Leur

Number of Reservoirs:

Slow (R):

Quick (R):

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

Heading	Properties	Explanation
Surface Type		Scheme name.
General Attributes	I_{max}	Infiltration capacity. [mm/day]
	f	Croptfactor Makkink. [-]
	$F0$	Moisture storage at $pF = 0$. [mm]
	$F2$	Moisture storage at $pF = 2$. [mm]
	$F4.2$	Moisture storage at $pF = 4.2$. [mm]
	Φ_{i0}	Initial moisture storage [mm]
	L_{B0}	Initial depth of the unsaturated zone [mm]
	n	Pore content [-]
	BL_{min}	Storage value in linear reservoir at which capillary rise is activated [mm]
	$P_{perc,max}$	Percolation to saturated zone between $pF = 0$ en $pF = 2$ (maximum). [mm/day]
	C_{max}	Maximum capillary rise [mm/day]
	$K_{surface}$	Time constant reservoir unpaved surface [day]
	K_{quick}	Time constant fast groundwater discharge. [day]
K_{slow}	Time constant slow groundwater discharge. [day]	
B	Distribution formula for 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.
Advanced		Use this button to modify the percolation and evaporation relations. DMS will open the Advanced Percolation Evaporation Relations dialog box. In this dialog the default relations for Precipitation an Evaporation can be overruled by the user

For technical details please refer to the RAM Reference Manual.

Related topics:

Area

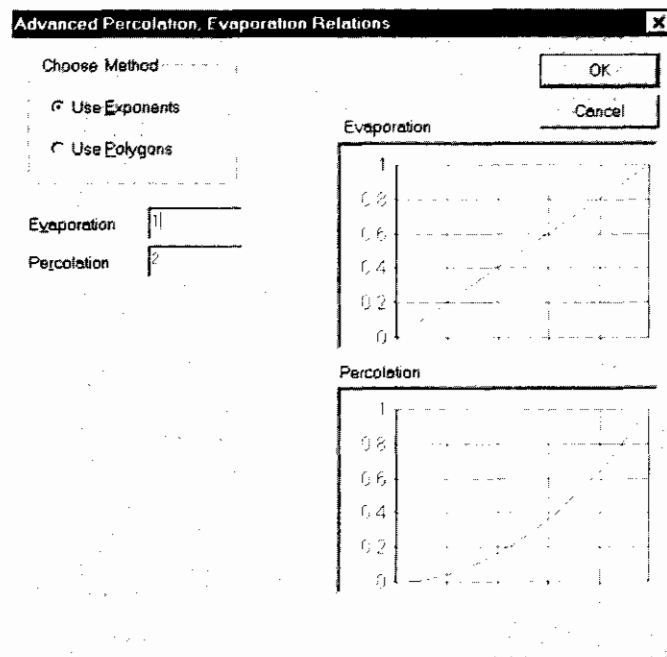
Unpaved Surface Scheme command

Advanced Percolatin Evaporation Relations dialog box

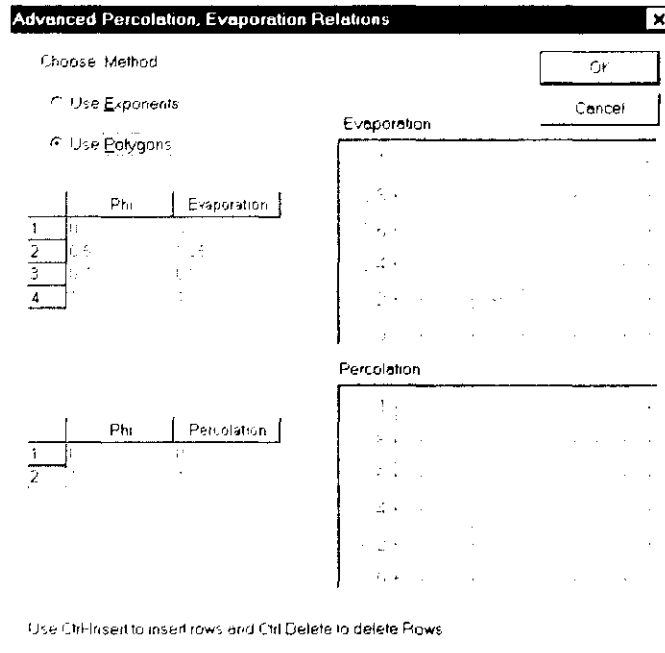
5.2.10 Advanced Percolation Evaporation Relations dialog box

The percolation and evaporation relations depend on the moisture content in the unsaturated zone. At default if the moisture content lies between $\phi_{pt=2.0}$ ('F2' in Unpaved Surface Settings dialog box) and $\phi_{pt=0}$ ('F0' in Unpaved Surface Settings dialog box) the relation between the moisture content and the percolation is assumed to a linear relation and likewise for the evaporation if the moisture content lies between $\phi_{pt=4.2}$ and $\phi_{pt=2.0}$.

In this dialog it is possible to override this default. The first possibility is an exponential relation as shown in the figure below (Percolation relation):



The second possibility to override this default is a piece wise linear relation (Evaporation relation):



For technical details please refer to the RAM Reference Manual.

Related topics:

Unpaved Surface Settings dialog box

5.2.11 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 Chezy coefficient for the friction in the siphon. The friction in the siphon is always calculated with the formula of De Chezy.	[m ^{1/3} /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	[m]
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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.

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.

Related topics:

Object Properties command

5.2.12 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.	[-]
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Mu Submerged	Mu for submerged flow situations in the culvert and can be defined in positive and negative direction.	[-]
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Initial Conditions	<p>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.</p> <p>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.</p>
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External Variables	<p>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.</p>
---------------------------	--

Related topics:

Object Properties command

5.2.13 Weir

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

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

Related topics:

Object Properties command

5.2.14 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 stop 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.
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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.
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RAM	No RAM specific data can be defined.
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Related topics:

Object Properties command

5.2.15 General Structure

General Structures are structures that 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

Related topics:

5.2.16 Calculation Point

Calculation points can be generated by DMS before a Dufflow calculation is made. The user can not add a calculation point to the network.

If the length of a section is longer than the Maximum length of the section (Maximum length is a property of a 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 size Δx , in the calculation. Output is available on calculation points. Calculation points will be visible in the Network window as gray diamonds after the Calculate command is given. The Calculation points will disappear by the Cleanup Network command.

Symbol:



The following properties can be described:

General

ID	Identification code of the node.	
Name	Name of the node.	
X-co-ordinate	The X-co-ordinate of the calculation point is calculated by DMS based, on the position of the calculation point in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Y-co-ordinate	The Y-co-ordinate of the calculation point is calculated by DMS based on the position of the calculation 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 calculation point is calculated by DMS, based on the positions of the node and the calculation point in the Network window. By entering a check mark behind the field the user can override the value calculated by DMS.	[m]
Dufflow	No Dufflow specific data can be defined.	
RAM	No RAM specific data can be defined.	

Related topics:

Object Properties command

Section

5.3 Network Object Commands

DMS offers to the following commands to modify the properties of objects in the Network window:

- Object Properties
- Select Object and Check Objects
- Flip orientation (Section)
- Bending point (Schematization point)
- Remove Object and Disconnect Object
- Remove Node and Join Sections (Node)
- Insert Node (Node)
- Offset Co-ordinates

With the following command an object in the Network window can be found:

- Locate Object



5.3.1 Object Properties (command)

Use this command to edit properties of the objects. After selecting this command, DMS displays the Object Properties dialog box. Use the Select Object command to select the object. It is also possible to open the Object Properties dialog box by double clicking with the left mouse button on the object in the Network window.

Tip	To change a property of all or all checked object (one type) to one value use the command from the menu bar. Choose in the Object Properties dialog box in the Object to Change list for 'All...' or 'Checked...'. In the latter case use the Check Objects command first.
------------	---

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(s).

Command:

Menu bar:	Edit - Objects - Properties...
Context menu:	In the Network window after the selection of an object - Properties...
Double-click:	In the Network window on a object.
Toolbar:	 (lists all objects of active scenario)  (lists only the selected object)

Related topics:

Object Properties dialog box

5.3.2 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
Calculation point

5.3.3 Select Object / Selection Mode

Use this command to select an object from the network.

Command:

Context menu: In Network window outside network objects - Selection mode

Toolbar: 

Related topics:

Check Objects

5.3.4 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.

Marking an Area in the Network window can also check objects. The Network window must then be in selection mode. Mark the selection area by pressing the left mouse button on one corner of the area, dragging it to the opposite corner and releasing the button there.

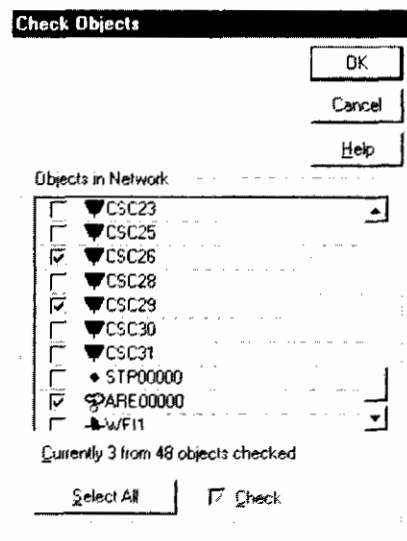
Command:

Menu bar: Edit - Objects - Select...

Toolbar: 

5.3.5 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.
- Gray 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

Select Object

5.3.6 Flip Orientation

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

Command:

Context menu: In the Network window after the selection of a section - Flip Orientation

Related topics:

Section

5.3.7 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:

Context menu: In the Network window after the selection of a schematization point - Bending Point

Related topics:


Schematization point

5.3.8 Remove Object

Use this command to remove an object from the network.

Command:

Context menu: In the Network window after the selection of an object - Remove object

Toolbar: 

Keys: DEL (after selecting an object)

If only two sections come together at a node, this node can be removed with the Remove Node and Join Sections command. By using this command the sections that come together at this Node will be joined. Otherwise – with the Remove Object command – two sections without a begin or end node will be created.

Related topics:

Disconnect Object

Remove Node and Join Sections

5.3.9 Disconnect Object

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

Command:

Context menu: In the Network window after the selection of an object – Disconnect Object

Related topics:

Remove Object

5.3.10 Remove Node and Join Sections

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

Command:

Context menu: In the Network window after the selection of a node - Remove node and Join Sections

Related topics:

Remove Object

Node

5.3.11 Insert Node

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

Command:

Context menu: In the Network window after the selection of a section - Insert Node

Related topics:

Node

5.3.12 Offset Co-ordinates

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

Command:

Context menu: In the Network window outside network objects - Special - Offset...

Related topics:


Object Properties dialog box

5.3.13 Locate Object

Use the Locate Object command to find an object in the Network window by giving the object ID. If the command is given by using the context menu 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.

Command:

Context menu: In the Network window - Locate Object...

Toolbar: 

You can use the toolbar by entering the object ID in the combo box followed by <Enter>. The searched item will blink in the Network window and saved in the drop down list for reuse.

Tip

It is also possible to search for internal object numbers that are used 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.

Related topics:

5.3.14 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.

Related topics:

Locate Object

5.4 Customizing Network Window

DMS offers the following commands to define the part of the Network to be displayed in the Network window:

- Entire Network
- Zooming in and Zooming out
- Pan network
- Current Position

With the following commands the appearance of the objects in the Network window can be changed:

- Show Object Types
- Network Properties, e.g. the point size of the objects.
- Display or hide IDs
- Display or hide Datatips
- Editable

5.4.1 Entire Network

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

Command:

Context menu: In the Network window outside network objects - Auto adjust limits

Toolbar:



5.4.2 Zooming Tool (Network window)

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:

Context menu: In the Network window outside network objects or in the Graph window - Zoom mode

Toolbar: 

Related topics:

Zooming out

5.4.3 Zooming out (Network window)

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:

Context menu: In the Network window outside network objects or in the Graph window - Zoom out

Toolbar: 

Related topics:

Zooming tool

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:

Context menu: In the Network window outside network objects - Pan mode

Toolbar: 

5.4.5 Current Position

Use the Current Position command to show or set the X- and Y-co-ordinate 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:

Context menu: In the Network window outside network objects - Special -

5.4.6 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:

Context menu: In the Network window outside network objects - Show Object Types

Related topics:

Show Network Object dialog box

5.4.7 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

5.4.8 Network Properties

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:

Point size Objects	Point size 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 bar: Edit - Window Properties...

Context menu: In the Network window outside network objects - Special - Drawing properties.

Toolbar: 


Related topics:

Display or hide ID's
Display or hide Datatips
Editable

5.4.9 Display or Hide ID's

Use this command to display or hide the ID's of the objects in the Network window.


Command:

Menu bar: Edit - Window Properties – Show: Text
Context menu: In the Network window outside network objects – Special - Show: Text
Toolbar: 

5.4.10 Display or Hide Datatips

Use this command to display or hide 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.

Command:

Menu bar: Edit - Window Properties – Show: Datatips
Context menu: In the Network window outside network objects – Special - Show: Datatips
Toolbar: 

5.4.11 Editable

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

Command:

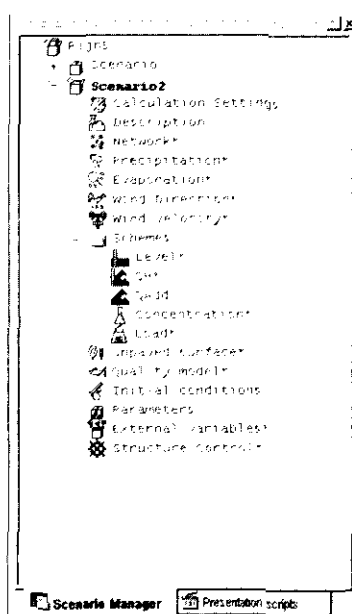
Menu bar: Edit - Editable
Context menu: In the Network window outside network objects - Special / Drawing properties - Editable

6. Scenario Manager

6.1 Usage of the Scenario Manager

A Scenario contains the input data of the model. The following types of data can be distinguished:

- Description of the scenario.
- Schematization / Network objects.
- Initial Conditions.
- Boundary Conditions stored in schemes.
- Other conditions and schemes.
(precipitation, evaporation, wind direction, wind velocity, structure control and unpaved schemes)
- Quality Model.
(Quality Model description file, parameters, external variables)
- Calculation Settings



The input data are divided into several subjects. These subjects are made visible in the Scenario Manager. Double clicking on the subject in the Scenario Manager will open a related window or dialog box. Clicking with the right mouse button on the subject in the Scenario Manager will open the context menu. The scenario, which is displayed in a bold font, is the so-called active scenario. Commands given by menu choices or toolbars will always be executed for the active scenario.

With the Scenario Manager the user also can define more scenarios in the same project. Other scenarios can be defined when the user wants to calculate the effect of changes in the base scenario.

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 the user alters some of the input parameters of a scenario, 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 as the base scenario. On the other hand, it is also possible to define a local copy of the input data for making modifications while keeping the base scenario unchanged.

Related topics:

Managing Scenarios
 Scenario description
 Network objects.
 Initial Conditions.
 Boundary Conditions
 Other conditions and schemes
 Quality Model
 Calculation Settings

6.1.1 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 when a new project is created. Scenarios that are created after this base scenario automatically contain references to the base scenario. New scenarios can be added with the New Scenario command. Using the Scenario Description command one can enter a short description of the scenario.

By adjusting the Scenario Properties, the user can easily combine input data from different scenarios.

Tip If in the Scenario Manager the subject is marked with an asterisk, this means that these data are used from another Scenario. The subjects in the base scenario are of course never marked.

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.

Note that if the Menu bar is used to give commands, these commands are always executed for the Active Scenario. Use the Set as Active Scenario command to change the Active Scenario.

Scenarios can be deleted with the Delete Scenario command. The base scenario can not be deleted.

Related topics:

Usage of the Scenario Manager

New Scenario

Scenario Description

Set as Active Scenario

Scenario Properties

Delete Scenario

6.1.2 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:

Context menu: In the Scenario Manager window after the selection of a project - New Scenario...

6.1.3 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.

The data of the new Scenario will be primarily based on the data of the base Scenario. If other data than the Calculation Settings, Description or Initial Conditions should be changed in the new scenario, than the Scenario Properties of the new Scenario should be changed.

Related topics:

New Scenario

6.1.4 Scenario Description

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

Command:

Menu bar: Scenario - Description...

Context menu: In the Scenario Manager window on Description - Edit...

Double click: In the Scenario Manager window on Description

Toolbar: 

6.1.5 Scenario Description dialog box

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

Related topics:

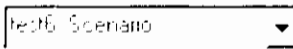
Scenario Description

6.1.6 Set as Active Scenario

Use this command to set the selected Scenario as active Scenario. All commands activated by choices in the menu bar or toolbars will be executed for the active Scenario.

Command:

Context menu: In the Scenario Manager window after the selection of a scenario - Set as Active Scenario

Toolbar: 

6.1.7 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.

The data of a Scenario are grouped into subjects. The subjects are mentioned in the following table:

Level	Subject	Data	Module	Relation with ...
Scenario	-	Description	-	
	-	Calculation Settings	-	
	Precipitation	Precipitation scheme	General	
	Evaporation	Evaporation scheme	General	
	Wind velocity	Wind velocity scheme	General	
	Wind direction	Wind direction scheme	General	
	Quality Model	Quality Model	Duflow	
	-	Parameters	-	(Quality Model)
-	Output Variables	-	(Quality Model)	
Schematization	Schematization	All objects and their relations	General	Object data
Object	-	Initial Conditions	-	(Quality Model)
	Object data	Object ID's / names, Co-ordinates / Length / Distance Structure properties, Cross sectional data, Boundary Cond. scheme names, External Var. scheme names	General	Quality Model / Schemes Quality Model / Schemes
	Structure control	Structure control	Duflow	
Scheme (contents)	Qadd	Qadd	General	Object data
	QH	QH	General	Object data
	Level	Level	General	Object data
	Concentration	Concentration	General	Object data / Quality Model
	Load	Load	General	Object data / Quality Model
	Unpaved Surface	Unpaved Surface	RAM	Object data
	External Variables	External Variables	Duflow	Object data / Quality Model

The source of every subject of the base scenario is always set to 'Own data' and can not be changed. This means that the base scenario owns it's own data.

In case of a new scenario – second, third etc. – the user can choose for each subject of that scenario to use the data from another scenario (reference) or to define a local copy and use this data (own data). The default value for the source of a subject in a new scenario is always set on a reference to the base scenario.

If in a new – i.e. second or third or etc. – scenario the Description, Calculation Settings, Parameter values, Output Variables or Initial Conditions should be changed, than it can be done without modifying the Scenario Properties.

If other data should be changed in a new scenario, the user should set the Property of the related subject to 'Own data'. In that case, the data is initially copied from the base scenario. When the new scenario owns the data, the data can be changed without effecting the data of other scenarios.

There are some restrictions in changing the source of a subject. It is not allowed to let a source of a higher level subject differ from a related lower level subject. (Scenario is the highest level, scheme the lowest level.). For example if you want to set the source for the subject Schematization to 'Own data', also the source of objectdata has to be set to 'Own data' because Schematization has a relation with Object data.

Examples

To analyse the effect on the results when using other **Initial Conditions**, do the following:

- Create a new scenario.
- Change the initial conditions in the new scenario (don't modify the Scenario Properties !)

To make calculations with different **Precipitation** intensities:

- Create a new scenario.
- Change the source of the subject Precipitation to 'Own data'.

To analyse the effects of building a **structure** in an existing network or changing a **cross sectional profile**, do the following:

- Create a new scenario.
- Change the source of the subjects Schematization and Object data to 'Own data'.

To analyse the effects of another **Boundary Condition** in an existing network, e.g. another Q-add time series you have two options:

- Create a new scenario.
- Change the source of the Object data to 'Own data', change the source of Q-Add scheme also to 'Own data'.
- Change in the new scenario the time series of the Q-Add scheme that is used as Boundary Condition.

Another solution is the following:

- Add a new Q-Add scheme to the **base** scenario.
- Create a new scenario.
- Change the source of the Object data to 'Own data'.
- Connect in the new scenario the new Q-Add scheme to the Node at the boundary of the network.

Quality Model

In case of Quality modelling the following combinations of properties are allowed in the new scenario 'Scenario1':

Object Data	Quality Model	External Variables	Description
Scenario	Scenario	Scenario	No changes in the Quality model compared to base scenario 'Scenario'
Own data	Scenario	Scenario	No changes in the Quality model compared to base scenario 'Scenario', but some changes in the Flow model compared to the Flow model of base scenario 'Scenario'
Own data	Scenario	Own data	Other values – other schemes – are used for the External Variables in scenario 'Scenario1' compared to base scenario 'Scenario'
Own data	Own data	Own data	'Scenario2' uses a different Quality model compared to base scenario 'Scenario'

Command:

Menu bar: Scenario - Properties...

Context menu: In the Scenario Manager window after the selection of a scenario – Properties...

Related topics:

Managing Scenarios

Scenario Properties dialog box (General)

Scenario Properties dialog box (DufLOW)

Scenario Properties dialog box (RAM)

6.1.8 Scenario Properties dialog box (General)

The Scenario may contain the input data itself or it may contain a reference 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.

Per subject the following information about the model is stored:

Schematization	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)

6.1.9 Scenario Properties dialog box (DufLOW)

This dialog box also contains a list of DufLOW specific subjects:

External Variables	The values in the External Variable schemes.
Quality Model	The used Quality Model and related data like parameters.
Structure Control	All data defined by the controlling of structures.

By selecting the option 'Generate version 2.05 files' the DufLOW files will be written in the old format. This option makes it possible to compare the results in DMS with the results from DufLOW for DOS 2.0x. Note that the 2.05 format is *not millennium proof*.

The default file format is 3.0.

Related topics:

- Scenario Properties
- Scenario Properties dialog box (General)
- Scenario Properties dialog box (RAM)

6.1.10 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 subjects:

Unpaved	The values in the Unpaved schemes.
----------------	------------------------------------

Related topics:

- Scenario Properties

Scenario Properties dialog box (General)

Scenario Properties dialog box (DufLOW)

6.1.11 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 the scenario from the project, but leave the files in the scenario directory intact (No) or do nothing (Cancel).

The base scenario can not be deleted.

Command:

Menu bar: Scenario - Delete

Context menu: In the Scenario Manager window after the selection of a Scenario - Delete Scenario

6.2 Initial Conditions

To start the computations, initial values for Level and Discharge are required. In case of a Quality Model also initial values for all state variables (concentrations) are required.

The user must provide these initial conditions for each DufLOW point, i.e. for each node, schematization point or structure. Use the Initial Conditions command to enter these initial values. The values 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 by modelling water quality the first part of the simulation period may result into non-realistic results. The transport rates and the characteristic time constants for the reactions control the time during which the effect of the initial conditions is perceptible. 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. This can be done with the New Initial Conditions command.

Related topics:

Initial Conditions (command)

New Initial Conditions

6.2.1 Initial Conditions (command)


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.

If the Initial Condition refers to a discharge or load on a node where three or more sections come together, the sum of the outgoing (or incoming) discharge or load should be entered. The initial ratio over the sections can be entered in the Object Properties dialog box of that node.

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

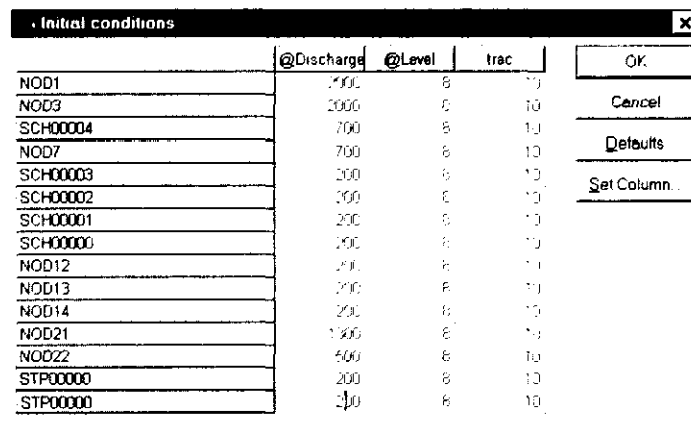
Command:

- Menu bar: Scenario – Initial Conditions...
- Context menu: In the Scenario Manager window on Initial Conditions – Edit...
- Double click: In the Scenario Manager window on Initial Conditions
- Toolbar: 

Related topics:

- Initial Conditions dialog box
- Initial Conditions dialog box (object oriented)
- New Initial Conditions

6.2.2 Initial Conditions dialog box



	@Discharge	@Level	trac
NOD1	700	8	10
NOD3	2000	8	10
SCH00004	700	8	10
NOD7	700	8	10
SCH00003	200	8	10
SCH00002	200	8	10
SCH00001	200	8	10
SCH00000	200	8	10
NOD12	200	8	10
NOD13	200	8	10
NOD14	200	8	10
NOD21	1000	8	10
NOD22	500	8	10
STP00000	200	8	10
STP00000	200	8	10

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 (concentrations) will be set to the default value as defined in the Quality Model description file.

Related topics:

- Initial Conditions
- Set Column dialog box

6.2.3 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 a new initial value for all objects.

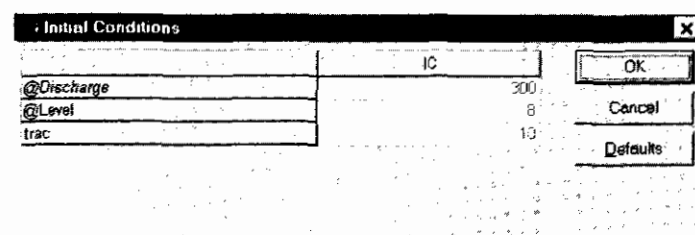
Related topics:

Initial Condition

Initial Conditions dialog box

6.2.4 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 (concentrations) 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

6.2.5 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.

Tip The New Initial Conditions command 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.

Command:

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

Related topics:

New Initial Conditions dialog box

Initial Conditions

6.2.6 New Initial Conditions dialog box

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

New Initial Conditions

Initial Date to initialize: Flow Quality

Situation of: Date: [dropdown] Time: [dropdown]

Source Flow:
Z:\Projecten\Flow\Flow.txt (standards)\Pip5\Scenario\scenario.PE5
Start: 1996/02/06 00:00:00 End: 1996/02/06 00:00:00
Steps in seconds: 1800

Source Quality:
Z:\Projecten\Flow\Flow.txt (standards)\Pip5\Scenario\scenario.PE5
Start: 1996/02/06 00:00:00 End: 1996/02/06 00:00:00
Steps in seconds: 1800

OK Cancel

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

6.3 Boundary Conditions

For a unique solution of the set of swallow water equations additional conditions have to be specified at the physical boundaries of the network. These additional conditions are called *Boundary Conditions*. *Boundary Conditions* can also be defined at *internal Nodes* or *Discharge* points in the network. *Boundary Conditions* can be specified as:

- Water levels and Discharges (*Q-Add*) 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 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.

Boundary Conditions, except for *Discharge-level* relations, are always a form of time series. Time series are stored in schemes. Therefore a *Boundary Condition* can be given as a property of an object in the *Boundary Conditions* dialog box by selecting the right scheme. A positive value for *Q-Add* in time series means incoming water (into the network), negative values mean outflowing water.

At the physical boundaries of the Network at least one kind of Flow *Boundary Condition* must be given; so this can be a *Level* scheme, a *Q-Add* scheme or a *QH-relation* scheme. If no scheme is selected at a *Node* at a physical boundary of

the network, DMS supposes that the Discharge at that Node is constant zero; a dead end in the schematization.

Tip Nodes and discharge points at which Boundary Conditions are defined, have a brighter color than the other nodes and discharge points.

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

In case of water Quality Modelling, pay attention to the following:

1. If you don't define Quality Boundary Conditions for a point, the concentration of the outflowing water (and also for the incoming water) is supposed to be zero. So no substances are leaving the system at this point.
2. If you define Quality Boundary Conditions for a point, these schemes will only be used for the incoming water. The concentration of the outflowing water is always equal to the concentration of the water mass at this point, which is calculated by DufLOW.

Precipitation and evaporation can only be used as Boundary Conditions in the RAM module. Based on values for precipitation and evaporation and the properties of the Area object, RAM will calculate the additional flow into the network at Area points. These calculated Q-add time series automatically become Boundary Conditions on these Area (schematization) points

Tip The Boundary Conditions for Level, Discharge, Concentration and Load can be read from or written to an external ASCII-file; a Time Series file (*.TSS). The format of the file is described in the DufLOW Reference Manual.
Use the Import Time Series command or the Export Time Series command to achieve this.

Wind direction and wind velocity, which may be significant in extensive shallow networks, can also be included.

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. In DMS these conditions are considered as Structure Control.

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:

Boundary Conditions dialog box

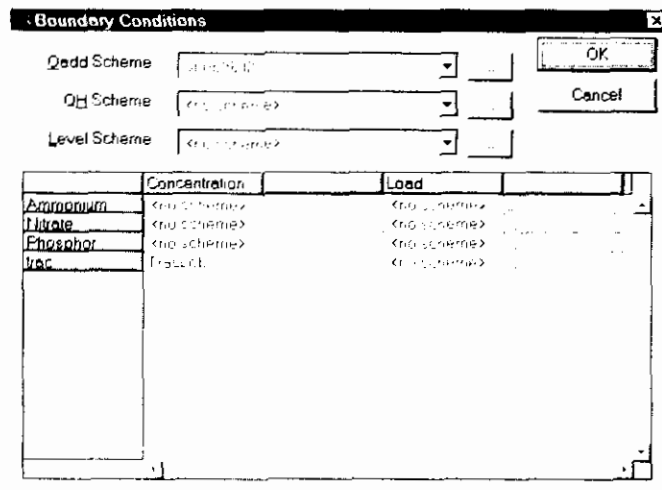
Import Time Series

Export Time Series

Other conditions and schemes

6.3.1 Boundary Conditions dialog box (object oriented)

The Boundary Conditions dialog box gives an overview of the selected schemes that 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 for Qadd, QH-Relation, Level, Concentration or Load.

Related topics:

Boundary Conditions

Node

Discharge point

Level scheme

QH-Relation scheme

Q-Add scheme

Concentration scheme

Load scheme.

6.3.2 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).

Level schemes are used as Boundary Conditions on Nodes.

Command:

Menu bar: Scenario - Schemes - Level...

Double click: In the Scenario Manager window on Level (Schemes)

Toolbar: 

Related topics:

Boundary Conditions

Usage of schemes and time series

6.3.3 QH-Relation Schemes

Use this command to set or modify the QH-Relation Schemes. DMS will show the Select QH-Relation Scheme dialog box. After the selection of a QH-Relation scheme you can set, import or modify QH-Relation time series in the Modify QH-Relation Scheme dialog box. The unit of discharge in DMS is m³/s, of level is m (metres).

QH schemes are used as Boundary Conditions on Nodes.

Command:

Menu bar: Scenario - Schemes - QH...

Double click: In the Scenario Manager window on QH (Schemes)

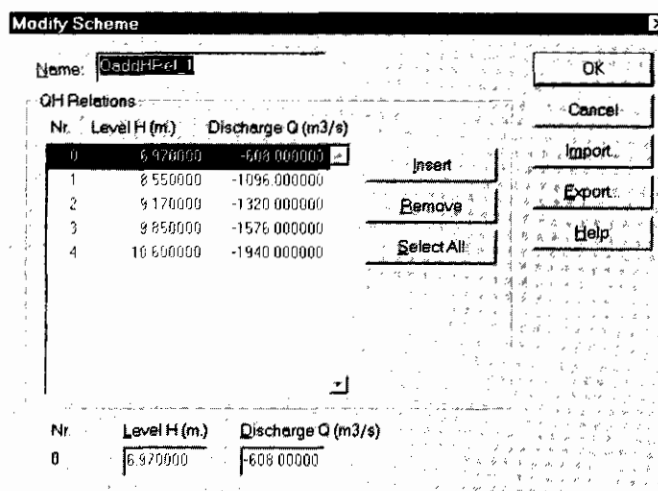
Toolbar: 

Related topics:

Boundary Conditions

6.3.4 Modify QH-Relation 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.



Use the following commands to modify the values for Level and Discharge:

- 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-Relation Schemes

6.3.5 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 m³/s.

Q-Add schemes are used as Boundary Conditions on Nodes and Discharge points.

Q-Add schemes can also be used as Boundary Conditions on Area points (schematization points) as a result of a RAM calculation.

Command:

Menu bar: Scenario - Schemes - Q-Add...

Double click: In the Scenario Manager window on Q-Add (Schemes)

Toolbar: 

Related topics:

Boundary Conditions

Usage of schemes and time series

6.3.6 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

In Concentration schemes Dufrow always displays 'mg/l' as the unit of state variables. Nevertheless is the real unit of a state variable defined by the users in the Water Quality description file:

Concentration schemes are used as Boundary Conditions on Nodes and Discharge points.

Command:

Menu bar: Scenario - Schemes - Concentration...

Double click: In the Scenario Manager window on Concentration (Schemes)

Toolbar: 

Related topics:

Boundary Conditions
Usage of schemes and time series
Quality Model

6.3.7 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:

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

In Load schemes DufLOW always displays 'g/s' as the unit of state variables. Nevertheless is the real unit of a state variable defined by the users in the Water Quality description file:

Load schemes are used as Boundary Conditions on Nodes and Discharge points.

Command:

Menu bar: Scenario - Schemes - Load...
Double click: In the Scenario Manager window on Load (Schemes)
Toolbar: 

Related topics:

Boundary Conditions
Usage of schemes and time series
Quality Model

6.4 Other Conditions and Schemes

DMS can also take other conditions into account like wind direction, wind velocity, precipitation, evaporation and structure control.

Precipitation and evaporation can only be used in the RAM. Based on values for precipitation and evaporation and the properties of the Area object, RAM will calculate the additional flow into the network at Area points. This calculated Q-add time series automatically become Boundary Conditions on these Area (schematization) points. An important property for the unpaved part of an Area is the type of soil. The properties of a type of soil is stored in a Unpaved scheme.

Wind direction and wind velocity may be significant in extensive shallow networks, can also be entered as a time series.

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. In DMS these conditions are considered as Structure Control.

Related topics:

Boundary Conditions

6.4.1 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.

Precipitation series will only be used in the RAM component.

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.

Because the unit of precipitation is mm/day, it also means that in this example total amount of precipitation that between 01:00 and 03:00 is:

$$300\text{mm} / 1 \text{ day} * 2 \text{ hours} = 25 \text{ mm.}$$

Command:

Menu bar: Scenario - Precipitation...

Context menu: In the Scenario Manager window on Precipitation - Edit...

Double click: In the Scenario Manager window on Precipitation

Toolbar: 

Related topics:

Other conditions and schemes

Usage of schemes and time series

Evaporation

6.4.2 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.

Evaporation series will only be used in the RAM component.

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	1
03:00	3

The discharge or concentration at 02:00 is equal to 2, the evaporation at 02:00 is however equal to 3.

Because the unit of precipitation is mm/day, it also means that in this example the total amount of evaporation between 01:00 and 03:00 is;

$$3\text{mm} / 1 \text{ day} * 2 \text{ hours} = 0.25 \text{ mm.}$$

Command:

- Menu bar: Scenario - Evaporation...
- Context menu: In the Scenario Manager window on Evaporation - Edit...
- Double click: In the Scenario Manager window on Evaporation
- Toolbar: 

Related topics:


- Other conditions and schemes
- Usage of schemes and time series
- Precipitation

6.4.3 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 wind direction in DMS is degree (360).

Wind Direction series will only be used in the Duflow component. To calculate the model with and without the influence of the wind direction use the option Exclude in the Calculation Settings dialog box.

Command:

- Menu bar: Scenario - Wind Direction...
- Context menu: In the Scenario Manager window on Wind Direction - Edit...
- Double click: In the Scenario Manager window on Wind Direction
- Toolbar: 

Related topics:


- Other conditions and schemes
- Usage of schemes and time series
- Wind Velocity

6.4.4 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.

Wind Velocity series will only be used in the DufLOW component. To calculate the model with and without the influence of the wind direction use the option Exclude in the Calculation Settings dialog box.

Command:

Menu bar:	Scenario - Wind Velocity...
Context menu:	In the Scenario Manager window on Wind Velocity - Edit...
Double click:	In the Scenario Manager window on Wind Velocity
Toolbar:	


Related topics:

[Other conditions and schemes](#)
[Usage of schemes and time series](#)
[Wind Direction](#)

6.4.5 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:

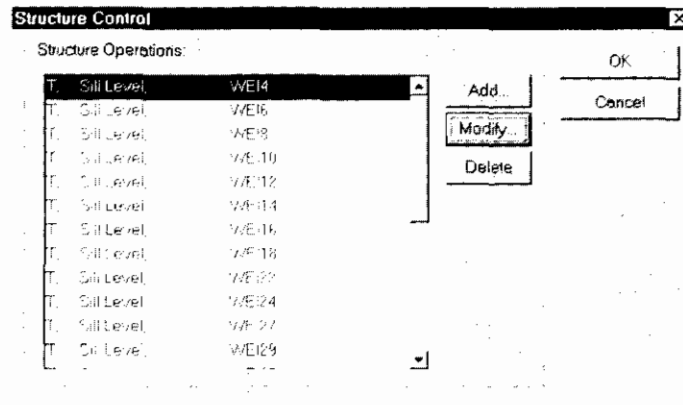
Menu bar:	Scenario - Structure Control...
Context menu:	In the Scenario Manager window on Structure Control - Edit...
Double click:	In the Scenario Manager window on Structure Control
Toolbar:	

Related topics:

[Structure Control dialog box](#)
[Other conditions and schemes](#)

6.4.6 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.

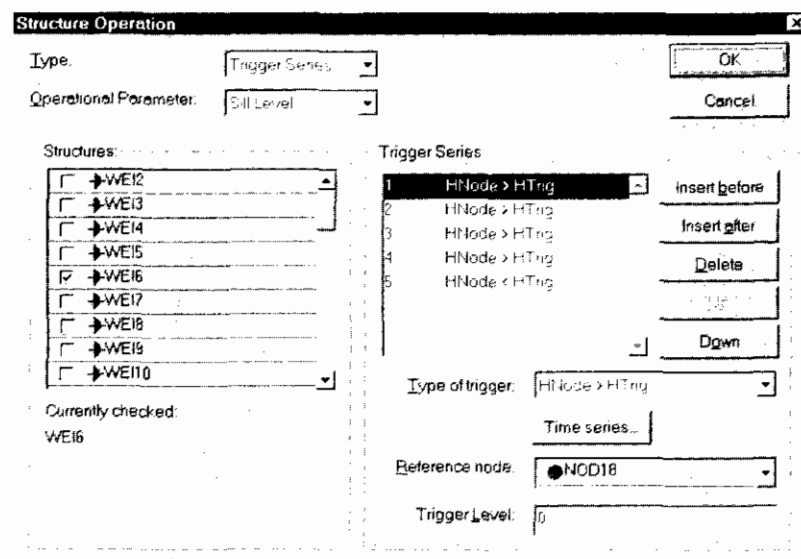
Related topics:

Structure Control

Structure Operation dialog box

6.4.7 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 consist 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

Entering a time series for the specified Operational Parameter can specify a Continuous Operation.

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.

The one of the following Type of Trigger Conditions can specify a Trigger itself:

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 time series.
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 time series.
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 time series.
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 time series.
Copy	A Trigger Condition that 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

Usage of schemes and time series

6.4.8 Unpaved Schemes

Use this command to set or modify the Unpaved Schemes. DMS will show the Select Unpaved Scheme dialog box. After the selection of an Unpaved scheme you can set the properties of the selected scheme.

Unpaved schemes are used as Boundary Conditions on the Network object Area and will only be used in RAM calculations.

Command:

Menu bar: Scenario – Unpaved Schemes ...

Double click: In the Scenario Manager window on Unpaved Surface.

Related topics:

Other conditions and schemes

Area

6.5 Usage of 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. Just connecting another scheme can change the properties of an object. 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.

Related topics:

Boundary Conditions

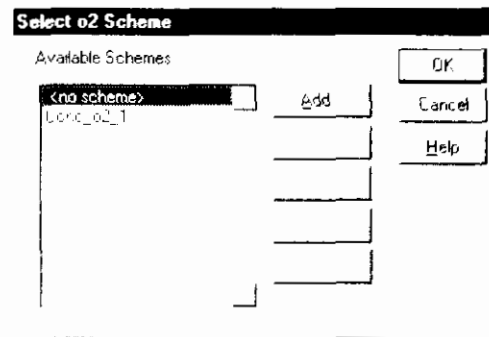
Select Scheme dialog box

Import Time Series

Export Time Series

6.5.1 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 that use the selected scheme.

Related topics:

Usage of schemes and time series

Modify Scheme dialog box

Scheme Usage dialog box

6.5.2 Scheme Usage dialog box

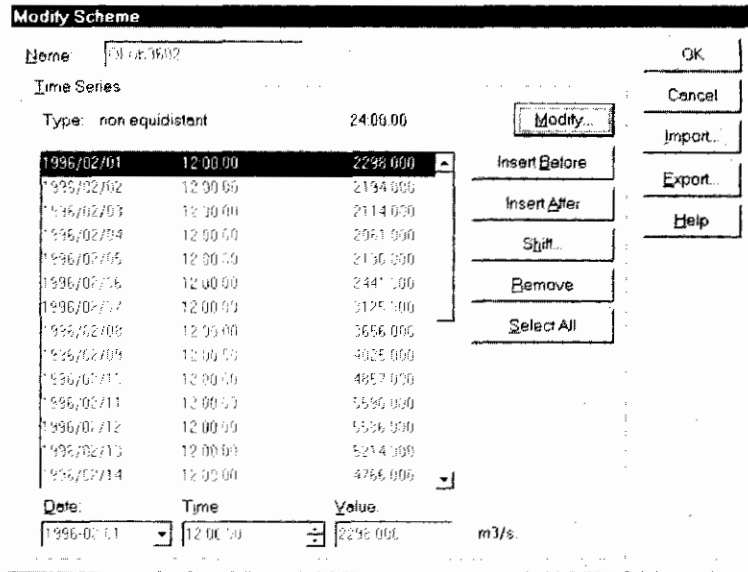
The Scheme Usage dialog box displays an overview of all objects that use the selected scheme.

Related topics:

Select Scheme dialog box

6.5.3 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.
- 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 `yyyy-mm-dd` or `yyyy/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 Dufflow input file. When later on, changes are made in the ASCII file, the Dufflow input file will not be updated.

Export

Enables you to export a time series to an external ASCII file.

Related topics:

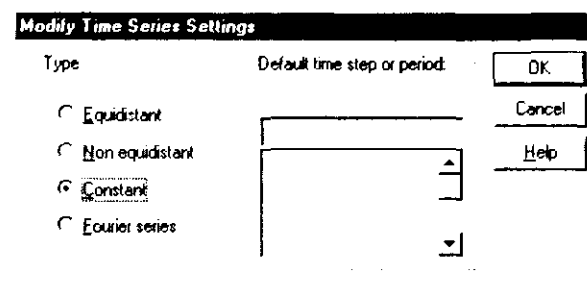
Select Scheme dialog box

Modify Time Series Settings dialog box

Shift Values dialog box

6.5.4 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.

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

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

- 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.

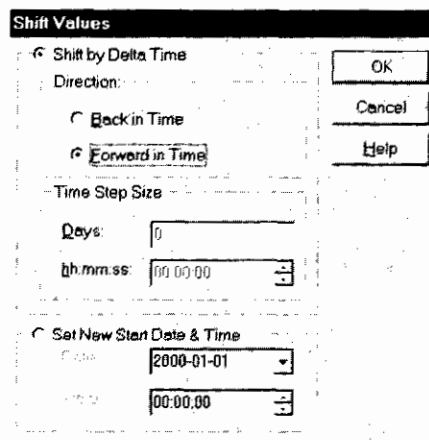
Whenever you change these settings and press OK, DMS will ask you to confirm the conversion.

Related topics:

Modify Scheme dialog box

6.5.5 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

6.5.6 Import Time Series

Use this command to read the Boundary Conditions for Level, Discharge, Concentration and Load from an external ASCII-file. DMS will open a dialog box to select the so-called Time Series file (*.TSS). The format of the file is described in the DufLOW Reference Manual.

Command:

Menu bar: Scenario - Schemes - Import Time Series ...

Context menu: In the Scenario Manager window after the selection of a scenario - Import Time Series ...

Tip

Create and change a simple Time Series file, which can be done with the Export Time Series command, instead of creating a large file from scratch.

Related topics:

Boundary Conditions

Export Time Series

6.5.7 Export Time Series

Use this command to write the Boundary Conditions for Level, Discharge, Concentration and Load to an external ASCII file. DMS will open a dialog box to set the name and directory of the so-called Time Series file (TSS). The format of the file is described in the Duflow Reference Manual.

Command:

Menu bar: Scenario - Schemes - Export Time Series ...

Context menu: In the Scenario Manager window after the selection of a scenario - Export Time Series ...

Related topics:

Boundary Conditions

Import Time Series

7. Quality Modelling

7.1 Building a Quality model

To set up a Quality Model the following steps should be carried out:

Define Quality Model

1. Open a project that contains a Flow model. Make sure that the computation is stable and that the results are correct.

Define Quality Model

2. Define a Quality Model description file. In this file the relevant quality processes can be described. A Quality Model description file is an ASCII-file with the extension **MOD**.

Language reference

More information about the syntax of this file can be found in the DufLOW Reference Manual, chapter Duprol.

The Quality Model description file can also be defined after step 4.

Simple example

A simple Quality Model description file like below contains the definition of a tracer named 'Trac'. The name of the file is 'Tracer.MOD':

```
/* DufLOW COURSE FEBRUARY 1998 */
/* SIMPLE TRACEMODEL */
/* HINNE PETTUMA 02-01-1998 */

WATER TRAC [10.000] mg/l ;TRACER
PAPM Ktrac [0.0100] 1/day ;DECOMPOSITION RATE TRAC

{
K1(TRAC) Ktrac;
}
```

Extended examples

When DMS is installed properly some Quality Models with extended Quality Model description files are available in the WinDufLOW/QualityModels directory. Information about how to obtain the Reference Manual for these Quality models can be found on the DufLOW internet site.

3. Save the Quality Model description file in the Scenario directory of the appropriate Project.
4. Add the Quality Model to the Project – Flow model - by entering the name of the Quality Model description file without extension in the DufLOW tab of the Calculation Settings dialog box. For example, enter the name 'Tracer'. If the Quality Model description file does not exist in the Scenario directory, DMS will prompt you to create it.

Edit Quality Model

You can modify the contents of the Quality Model description file by choosing the Edit Quality Model command. Use this command also to define a new Quality Model description file if it was not created already in step 2.

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.
------------	---

Compile Quality model

- If the Quality Model description file is correct, it can be compiled by choosing the Compile Quality Model command.

DUPROL

The part of the DufLOW package, which compiles the Quality Model description file and generates a Quality Model output file, is called DUPROL. The Quality Model output file, which has the extension **MOB**, can be read by the DufLOW calculation process. The Quality Model output file (*.MOB) is stored in the same directory with the same name as the Quality Model descriptions file.

Initial Conditions

- If the Quality Model description file is compiled successfully, the Initial Conditions for the State Variables – concentrations - can be entered. Choose the Initial Conditions command to add these to the Network. Note that if slow quality processes are defined in the Quality Description file, the effect of the initial concentrations can be significant.

Boundary Conditions

- Define the Quality Boundary Conditions. Quality Boundary Conditions can be entered as time series for concentration or load. Use the Boundary Conditions command to connect a scheme to an object. Boundary Conditions for Quality can only be defined at Nodes or Discharge points. DufLOW always displays the unit mg/l for concentration and g/d for load. Nevertheless does the user in the Quality Model description file define the real unit for a state variable. Pay attention to the following:
 - If you don't define Quality Boundary Conditions on a point, the concentration of the outflowing water (and also for the incoming water) is supposed to be zero. So no substances are leaving the system at this point.
 - If you define Quality Boundary Conditions on a point, these schemes will only be used for the incoming water. The concentration of the outflowing water is always equal to the concentration of the water mass at this point, which is calculated by DufLOW.
 - 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. DufLOW will generate warnings if this is the case.

Parameters

- Check the values for the Parameters that are defined in the Quality Model description. Use the Parameters command to open the Parameters dialog box. The initial values for the parameters are copied from the Quality Model description file.

External Variables

- Enter schemes for the External variables. External variables can be defined in the Quality Model description file for input data that are space and/or time dependent.

Dispersion

If the Quality Model description file does not contain any External Variable, then at least one or more schemes for Dispersion should be entered. However the dispersion coefficient D (identified by 'd') does not have to be declared in the Quality Model description file, it has to be defined in the Quality Model itself.

The value of the dispersion coefficient D either can be defined by the user or can be calculated using the properties of the flow ($D=D_0 + \alpha_k f(\text{flow})$). For technical details please refer to the DufLOW Reference Manual.

In the first case a scheme for the external variable D_0 ('d' in DMS) has to be created and assigned to the network objects. In the latter case also a scheme for α_k ('alfak' in DMS) has to be created. In case α_k equals 0 (when no scheme is created), dispersion is not calculated by the model and the user supplied values (for external variable 'd') are used.

Use the External Variables command to add or modify External Variables schemes to the project. External Variables schemes can be connected to Nodes, Schematization points and structures.

DufLOW offers two options to connect External Variables schemes to objects.

Connecting to all objects

- The first option is the easiest. Use the Connect to All Objects command to connect an External Variable scheme to all objects in the Network.

Connect to a single object

- If an External Variable is space dependent you can connect an External Variables scheme to an object by using the External Variables command. If this option is used, make sure you connect a scheme to every object -- nodes, schematization points and structures - of the network.
Using this option overwrites the scheme that is selected in the first option.

Note that an External Variables scheme is in fact a property of an object. But if the Connect to All Objects command is used, the selected scheme is not displayed in the Object Properties dialog box!

Calculation Settings

9. Before a Quality calculation can be started the some calculation options should be changed. Use the Calculation Settings command to open Calculation Settings dialog box. Check the following options:

- The time step for Quality at the General tab must fit to the Quality processes in the Quality Model description file.
- At the DufLOW tab the Type of Calculation must be set on **Flow&Quality**.
Use the Output Variables command - on the same tab - to set variables of the Quality Model to be available for output. Default no Variables are selected for output!

Calculate

Choosing the Calculate or Update All command activates the calculation.

7.2 Quality Model Commands

The commands in this paragraph can only be used if a Quality Model is defined within the project.

The following commands are available:

- Edit Quality model
- Compile Quality model

- Parameters
- External Variables

Related topics:

Building a Quality Model


7.2.1 Edit Quality Model

Use this command to edit the Quality model. The contents of the Quality Model description file appear as a window in the Workspace, where it can be edited.

The Quality Model description file is a text-file containing the descriptions of the quality processes. The syntax of these descriptions is explained in the Dufflow Reference Manual, chapter DUPROL. The name of the Quality Model description file must be specified in the Calculation Settings under the Dufflow 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 bar:	Scenario - Quality - Edit...
Context menu:	In the Scenario Manager window on Quality Model - Edit...
Double click:	In the Scenario Manager window on Quality Model
Toolbar:	

Tip While editing the Quality model the position of the cursor is displayed in the right area of the Status bar.

Related topics:

Building a Quality Model

Compile Quality model

7.2.2 Compile Quality Model

Use this command to compile the Quality Model description file *.DUPROL. compiles the process descriptions of the *.MOD file and generates a Quality Model output file which can be read by the Dufflow calculation process. The Quality Model output file will be written in the scenario directory with the same name as the Quality description file, but gets the extension *.MOB.

Compiling the Quality Model description file will not change the values of the parameters or the initial values of the variables.

If the compilation of the Quality Model stops without completion, it can be terminated with the Terminate Calculation command.

Command:

Menu bar:	Scenario - Quality - Compile.
Context menu:	In the Scenario Manager window on Quality Model - Compile.

Keys: CTRL+F7

After compiling Duflow will give a warning about the relinking of the Quality Variables. If the Quality Model description file is compiled successfully the Quality Variables will be relinked without any problems. Otherwise, if problems occur during compilation, the Quality Variables will not be linked.

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.

Related topics:

[Building a Quality Model](#)

[Edit Quality model](#)

7.2.3 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 bar: Scenario - Parameters...

Context menu: In the Scenario Manager window on Parameters - Edit...

Double click: In the Scenario Manager window on Parameters

Toolbar:  :

Related topics:

[Building a Quality Model](#)

[Parameters dialog box.](#)

7.2.4 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](#)

7.2.5 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 Dufflow tab. DMS will show the External Variables dialog box (object oriented) with the selected schemes for the External Variables of the selected object.

An External Variables scheme can be connected to all objects of the network by using the Connect to All Objects command. If this command is used, the selected scheme will not be displayed in the Objects Properties dialog.

Dispersion

Note that the dispersion coefficient D in DMS identified by a 'd' - is also considered to be an external variable although it is not declared in the Quality Model description file.

The value of the dispersion coefficient D either can be defined by the user or can be calculated using the properties of the flow ($D=D_0 + \alpha \cdot f(\text{flow})$). For technical details please refer to the Dufflow Reference Manual. In the first case a scheme for the external variable D , ('d' in DMS) has to be created and assigned to the network objects. In the latter case also a scheme for α , ('alfak' in DMS) has to be created. In case α equals 0 (when no scheme is created), dispersion is not calculated by the model and the user supplied values ('d') are used.

Command:

- Menu bar: Scenario - External Variables...
- Context menu: In the Scenario Manager window on External Variables - Edit...
- Double click: In the Scenario Manager window on External Variables

Related topics:

- Building a Quality Model
- External Variables dialog box (object oriented)
- Usage of schemes and time series
- Connect to All Objects command

7.2.6 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

7.2.7 Connect to All Objects

Use this command to connect an External Variable scheme to all relevant objects of the network. These objects are the Nodes, Schematization points and the Structures.

If this command is used, the selected External Variables scheme will not be displayed in the Object Properties dialog box on the Dufflow tab.

The scheme, which is connected to an object by using this command, can be overwritten by selecting an other scheme in the Object Properties dialog box on the Duflow tab.

Command:

Context menu: In the Scenario Manager window on External Variables – Connect to all objects....

Toolbar: 

Related topics:

[Building a Quality Model](#)

[External Variables](#)

8. Calculation

8.1 Calculation Preparation

Before a calculation can be started, first some general information concerning the calculation should be entered in the Calculation Settings dialog box. The output of a calculation of DMS strongly depends on the options that are chosen in this dialog box.

Related topics:

Calculation Settings

8.1.1 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 Calculation 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 bar: Scenario – Calculation Settings...

Context menu: In the Scenario Manager window on Calculation settings - Edit

Double click: In the Scenario Manager window on Calculation settings

Toolbar: 

Related topics:

Calculation Settings dialog box (general)

Calculation Settings dialog box (RAM)

Calculation Settings dialog box (Duflow)

8.1.2 Calculation Setting dialog box (General)

Calculation Settings

General | RAM | DUFLOW

Start computation:

Start output:

End:

Time Step Size:

Computation Flow:

Computation Quality:

Output Flow:

OK Cancel Help

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 Duflow Reference Manual gives suggestions for the choice of the hydraulic time step. The time step size should never be larger than the step size used in the time series in the scenario.
Time Step size, Computation Quality	Time interval for the quality part of the model. The Duflow 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.

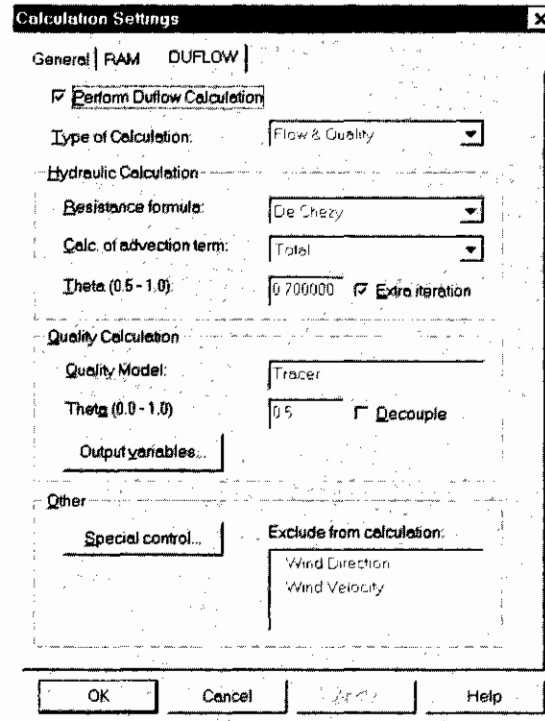
Related topics:

Calculation Settings

Calculation Settings dialog box (RAM)

Calculation Settings dialog box (DufLOW)

8.1.3 Calculation 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 (RAM tab).

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

	<p>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.</p>
Resistance formula	<p>The channel friction can be calculated using:</p> <ul style="list-style-type: none"> - the formula of De Chézy. The "resistance" coefficient C in the definition of the sections is from the basic formula: $v=C \sqrt{R \cdot I}$ - the formula of Manning. The "resistance" is the Manning coefficient k (1/m) from the basic formula $v=k \cdot R^{2/3} \cdot I$. In the actual calculation $C=k \cdot R^{1/6}$ is substituted in the formula of De Chézy. <p>The value of C is calculated for each time step during the simulation. Default: De Chézy</p> <p>More information about the Resistance formula is described in the Duflow Reference Manual.</p>
Calc. of advection term.	<p>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".</p> <p>More information about advection is described in the Duflow Reference Manual.</p>
Theta	<p>The factor controlling numerical damping. Default: 0.55</p> <p>The value for theta may range from 0.5 to 1.0.</p> <p>The highest precision in the results will be received when the value for theta is 0.5. At that stage the scheme for solving the shallow water equations is second order precise in time and space. But the calculation can become unstable. If so, the theta can be increased. More info about unstable calculations can be found in the paragraph Stability Problems.</p> <p>If theta is equal to 1.0, the calculation has the highest stability, but the solving of the scheme is only first order precise in time and space.</p> <p>More information about Theta is described in the Duflow Reference Manual.</p>
Extra iteration	<p>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.</p>
Quality Model	<p>Name of the ASCII file that contains 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.</p> <p>To edit the quality model file use the Edit Quality Model command.</p>
Theta (0.0-1.0)	<p>The factor controlling the numerical solution of the advection and dispersion equation. The value zero</p>

($\theta=0$) 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 or wind direction from the calculation.

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

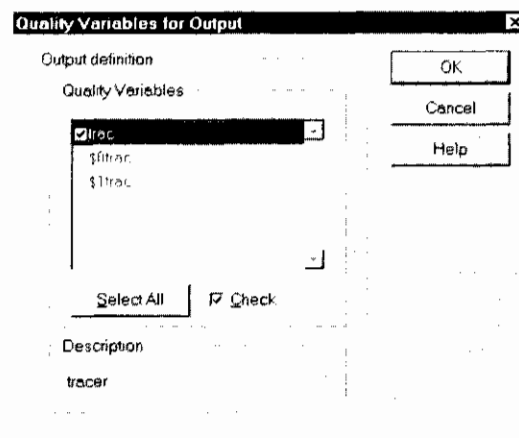
Related topics:

- Calculation Settings
- Calculation Settings dialog box (general)
- Calculation Settings dialog box (RAM)
- Output Variables dialog box
- Special Control dialog box

8.1.4 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 dialog box (DufLOW)

8.1.5 Special Control dialog box

The Special Control dialog box offers the following options:

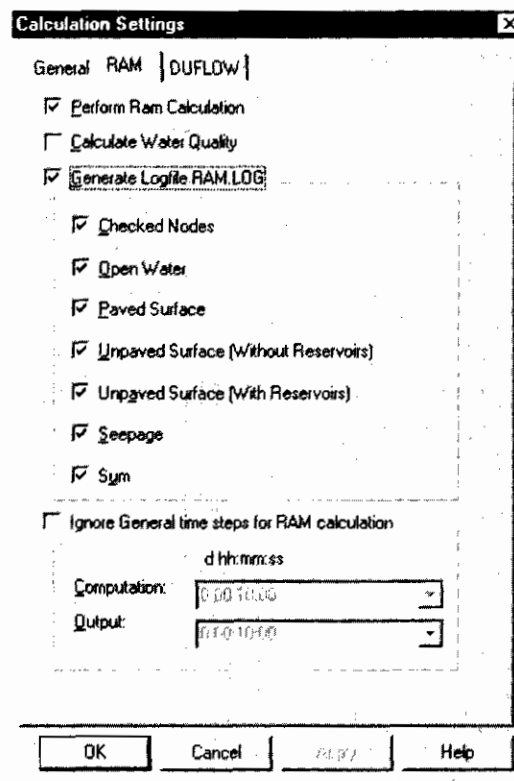
Create intermediate flow file	A dump file will be generated during simulation using option Flow. The intermediate flow result file (*.DMP) will be used to simulate transport if a quality calculation is performed. In this *.DMP file information about volumes, flows etc. is stored, which is read during 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
Threshold 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 Floor level (bottom) of the cross section. More information about the dry-flood procedure is described in the Outflow Reference Manual. Default: 0.10 metre

Related topics:

Calculation Settings dialog box (Duflow)

Structure Operation dialog box

8.1.6 Calculation 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 | The steps in the calculation can be stored in ASCII log-files for calculation checks. The logfiles will be written in the scenario directory.

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 |

Ignore general time steps for RAM calculation

Include the sum of all surfaces and seepage.

By choosing this option the time step sizes on the tab General will be ignored in the RAM calculation.

RAM will use the on this tab specified step sizes for computation and output.

Tip

The time step specified for the RAM calculation can be much larger than the time step that is required by the DufLOW flow-model for a stable calculation. But the RAM time step size should never be larger than the step size that is used in the time series for Precipitation and Evaporation.

Related topics:

Calculation Settings

Calculation Settings dialog box (general)

Calculation Settings dialog box (DufLOW)

8.2 Calculation Commands

A DufLOW calculation is divided into three steps. In the first step the Network is converted. In this conversion calculation points are defined and - based on the Cross Sections - the cross sectional profile at the DufLOW points are defined. 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 is described in the DufLOW Reference Manual. Finally the calculation is performed and the results are stored in the results files (DRES contains the flow results, DREK contains the quality results).

The above steps are performed sequentially by giving the Update All / Calculate command but also can be performed separately by first giving the Convert Network, Write DufLOW Files and finally the Run DufLOW Model command.

A RAM calculation - if the RAM component is installed - will always be carried out before the DufLOW calculation. 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

If the results of the RAM calculation satisfies, don't forget to uncheck the option Perform RAM Calculation in the Calculation Settings - RAM tab.

Because the results of the RAM calculation are saved as Q-Add Boundary Conditions Schemes for Areas, you don't need to run RAM every time you want to make a DufLOW calculation.

Related topics:


Calculation Settings

8.2.1 Update All / Calculate

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. The referred objects in the Network window will turn red. Use the Reset Errors command to give the objects their original color back.

Command:

Menu bar:	Calculation - Update All
Context menu:	In the Scenario Manager window after the selection of a scenario - Calculate
Toolbar:	
Keys:	F5

Tip The calculation can be stopped by giving the Terminate Calculation command.

Related topics:

Calculation Commands
Calculation Settings
Terminate Calculation
Output window
Stability Problems

8.2.2 Convert Network

Use this command to convert the DMS Network into a network that can be written to the DufLOW files.

By using this command DMS will show the calculation points in the Network window. Use the Cleanup Network command, to remove the calculation points from the network.

Command:

Menu bar:	Calculation - Convert Network
Keys:	F6

Related topics:

Calculation Commands
Write DufLOW files
Cleanup Network command

8.2.3 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.

The executable CDuflow.exe can read DufLOW files. CDuflow.exe performs the DufLOW calculation. The DufLOW-files are stored in the scenario directory.

The following DufLOW file-types can be distinguished:

File type	Extension	Description
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.
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.
SUF ID File	*.SID	This file contains the co-ordinates of the Network objects and the relation between the Objects ID and internal DufLOW ID.

For more detail information about the DufLOW files is described in DufLOW Reference Manual. The format of the DufLOW files - version 2.05 or version 3.0 - can be defined in the Scenario Properties dialog box on the DufLOW tab.

Command:

Menu bar: Calculation - Write DufLOW Files

Related topics:

Calculation Commands

Convert Network

Run DufLOW model

8.2.4 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 / Calculate 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 bar: Calculation - Run DufLOW Model

Keys: F7

Related topics:

Calculation Commands

Calculation Settings

Write DufLOW files

Terminate Calculation
Output window
Stability Problems

8.2.5 Cleanup Network

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

After giving a new Calculate command, Calculation points will be generated again.

Command:

Menu bar: Calculation – Cleanup Network
Context menu: In the Network window - Cleanup Network

Related topics:

Calculation point
Update All / Calculate
Convert Network

8.2.6 Reset Errors

Use this command to reset the errors in the Network window. DMS will change the red colored objects, which were displayed red when during calculation errors occurred regarding to these objects, to their original color.

Command:

Menu bar: Calculation – Reset Errors

Related topics:

Update All / Calculate
Run DufLOW model

8.2.7 Terminate Calculation

Use this command to terminate the RAM calculation, the DufLOW calculation or the Duprol compilation.

Command:

Menu bar: Calculation – Terminate Calculation

Related topics:

Update All / Calculate
Run DufLOW model
Compile Quality model

8.3 Stability problems

During a calculation the solving of the numerical scheme can become unstable.

In case of a Flow calculation DMS will display error messages 3017, 3019 or 3051. Perhaps DMS will display a message about a mathematical error at the beginning of the calculation.

In case of an unstable water quality calculation the calculated concentrations can become negative or a time related graph of a concentration looks like a saw.

8.3.1 Flow Calculation

If the water quantity computation is unstable, try to find where the computation becomes unstable.

There are several ways to make a computation more stable, some of them are:

If the problem occurs at the beginning of the simulation, this can be caused by an error in the initial conditions. In this case fill out as much real values as possible and avoid big steps in the network.

If the location is found, verify then if dry flood is the case. Duflow can cope with tide sections. (See the Duflow Reference Manual for the functioning of the dry flood procedure.) When fluctuations in the water level are too large it is possible that Duflow computes a negative flow area. This can be prevented by computing with smaller time steps or by raising the threshold level (Threshold level: Calculation Settings / Special Control) for tideland.

Check whether the flow is supercritical (Froude > 1). In principle Duflow is not suitable for such flows. If such situations occur the simulation can be made stable by lowering the Chezy value at the spot. The flow is no supercritical (subcritical, Froude < 1) if for every part of the network the following formula is valid:

$$\frac{v^3 \cdot B}{g \cdot A} < 1$$

where:

- v Mean flow velocity (averaged over the cross sectional area) [m/s]
= Q/A where Q discharge
 A cross sectional flow area
- g Acceleration due to gravity [m/s²]
- B Cross sectional flow width [m]
- A Cross sectional flow area [m²]

Check whether there is an increase in flow area between two calculation points. So a jump at the spot of a calculation point is of no importance. Big changes in the flow area can lead to instabilities. See also the Duflow Reference Manual about the "Advection term". In Calculation Settings - General tab the calculation of the advective term can be ignored or suppressed. The schematization can also be modified, to force a jump in the flow area, instead of a more gradual change.

In general the user has the following possibilities to increase the stability of the calculation:

1. Decrease the time step of the calculation - Δt - (Calculation Settings - tab General: Time Step Size Flow)
2. Decrease the calculation length of the sections. Initially the length of the section is used for the computation with space step size Δx . The space step size of a section can be changed by entering a value

for 'Maximum length' (Object Properties - tab Duflow) that is smaller than the length of the section. At computation time the section is split up in parts of Δx that are equal or slightly smaller than the value of 'Maximum length'.

3. Increase the value for 'theta' (Calculation Settings – tab Duflow).
4. Decrease the Chezy-value.
5. Adjust the threshold value of the dry-out procedure. (Calculation Settings – tab Duflow – Special Control)

If finally these efforts result in a stable calculation, it is recommended to overwrite the initial conditions in the model with the results of the stable computation by using the New Initial Conditions command. It's obvious not to use the values at the beginning of the computation period!

Related topics:

Update All / Calculate
 Run Duflow model
 Calculation Settings
 Section
 Cross Section

8.3.2 Quality Calculation

If the water quality calculation becomes unstable, e.g. the results contains negative concentrations, roughly two causes can be distinguished:

First, the instability is caused by the part in which the transport of the substances is calculated.

Secondly, the instability is caused by the water quality process, which is defined by the user in the quality model.

If the water quality calculation becomes unstable this is most of the time caused by a too large value of the Peclet number ($Pe > 2$). If a chart is drawn where the concentration of a substance is shown against it's position ('Space Related Graph') it results most of the times in a heavily toothed chart, where for each calculation point alternating a minimum and a maximum is show.

The Peclet value is defined by:

$$Pe = \frac{v * \Delta x}{D}$$

where:

Pe	Peclet value [-]
V	Mean flow velocity (averaged over the cross sectional area) [m/s] = Q/A where Q discharge A cross sectional flow area
Δx	Section length (distance between two calculation points) [m]
D	Dispersion coefficient [m ² /s]

The solution to this problem can be found by reducing the section length or increasing the dispersion.

If the water quality processes are the pressure point, you will have to look at the quality processes themselves. It is general difficult to give a verdict about this. The time step must be adjusted to the fastest running process in the quality model. The time step must be smaller or equal to the time scale on which the processes take place.

Related topics:

[Update All / Calculate](#)

[Run DufLOW model](#)

[Calculation Settings](#)

[Section](#)

[Cross Section](#)

[Building a Quality Model](#)

[External Variables](#)

9. Results

9.1 Presentation of the Results

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

- As Text in a table as a function of time.
- In a Time Related Graph.
- In a Space Related Graph.
- In the Network window in Presentation Mode

Text and graphs are displayed in windows. These windows appear in the Workspace. A text or graph 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.

Results can also be displayed in the Network window. In a Presentation Script is defined how the results have to be displayed in the Network window. To use the Presentation Mode a Presentation Script must be selected.

9.2 Text Window

In a text window the data are displayed in a numerical way and can be written to an external file. Use the New Text window command to open it.

The following commands are available in a Text window:

- Save Results
- Copy Results
- Transpose Table
- Change Table contents
- Change Font

Related topics:

New Text window

9.2.1 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. After the selection of the data, which should be displayed, DMS will open a New Text window. The Text window always appears in the Workspace.

Command:

Menu bar: View - New Text Window...

Context menu: In the Scenario Manager window after the selection of a scenario - New Text Window...

Toolbar: 

Related topics:

Text window

Time Related Graph dialog box

9.2.2 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:

Context menu: In the Text window - Save...

Related topics:

Text window

9.2.3 Copy Results

Use the Copy Results command to copy the selected results to Clipboard. Use the Paste command in another application to copy the results to that application.

Command:

Context menu: In the Text window - Copy...

Related topics:

Text window

9.2.4 Transpose Table

Use the Transpose Table command to transpose the Text table.

Command:

Context menu: In the Text window - Transpose...

Related topics:

Text window

9.2.5 Change Table Contents

Use the Change Table command to reset the display options per source and per object. After selecting the command, DMS will show the Time Related Graph Dialog box. The options in the Time Related Table dialog box are explained in the Time Related Graph dialog box.

Command:

Menu bar: Edit – Graphs/Table...

Context menu: In the Text window - Table

Related topics:

Time Related Graph dialog box

Text window

9.2.6 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:

Context menu: In the Text window - Font...

Related topics:

Text window

9.3 Graph Windows

Two types of graph can be opened:

- Time Related Graph
- Space Related Graph

Both graphs are opened as windows in the Workspace.

There are several commands available to Customize Graph windows.

Related topics:

Time Related Graph

Space Related Graph

9.3.1 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. After the selection of the data, which should be displayed, DMS will open a New Time Related Graph window. The Time Related Graph window always appears in the Workspace.

Command:

Menu bar: View - New Time Graph Window...

Context menu: In the Scenario Manager window after the selection of a scenario - New Time Graph Window...

Toolbar: 

It is also possible to alter the graphs contents, colors or properties to the currently open graph window: see Customizing Graph window.

Related topics:

Graph windows

Time Related Graph dialog box

Display Time Graph per section

Add Time Graph to current graph

9.3.2 Display Time Graph per section

To display a time related graph for one section:

Command:

Context menu: In the Network window after the selection of a section or structure - Duflow - New Time Graph Window...

Related topics:

Graph windows

New Time Graph window

Add Time Graph to current graph

9.3.3 Add Time Graph to current graph

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

Command:

Context menu: In the Network window after the selection of a section or structure - Duflow - Add To Time Graph Window...

Related topics:

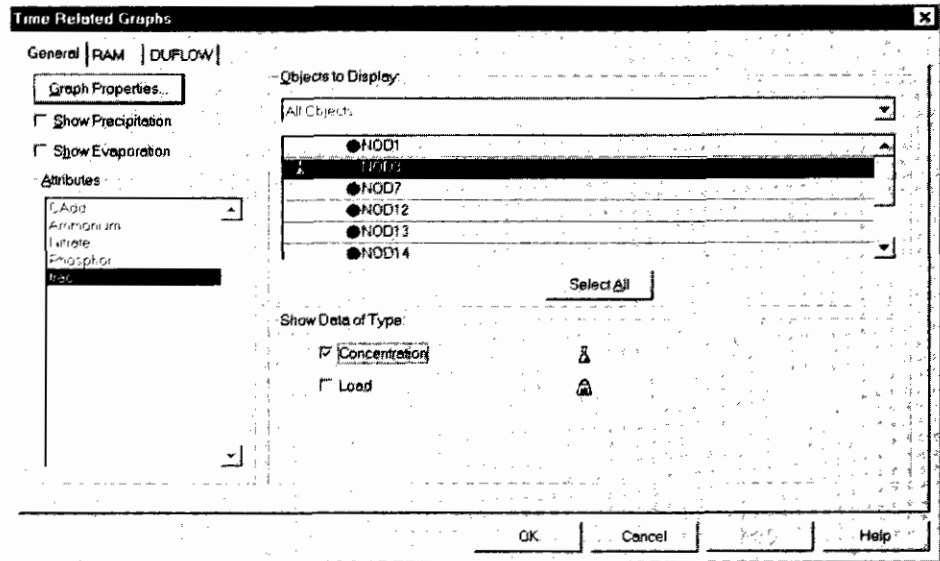
Graph windows

New Time Graph window

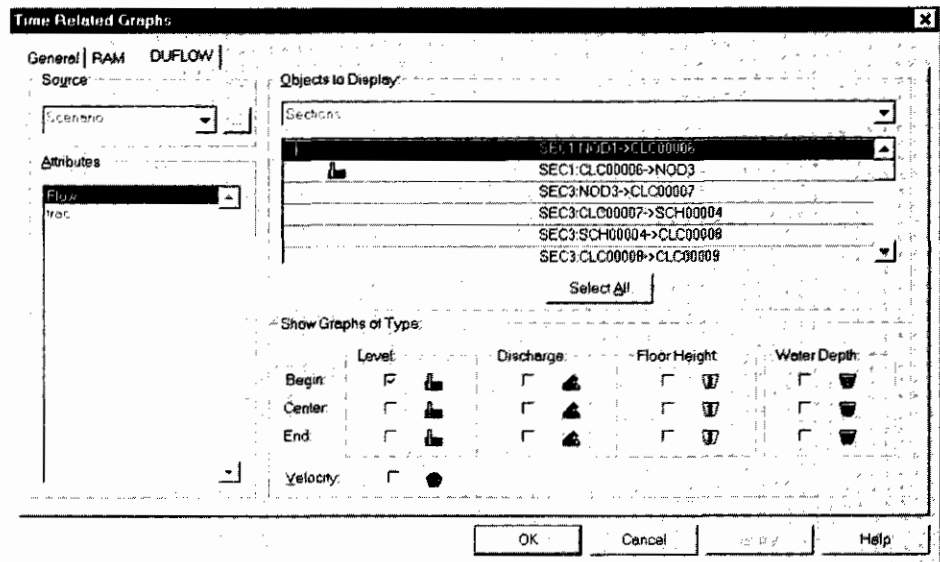
Display Time Graph per section

9.3.4 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 i.e. the boundary conditions.



The tabs Duflow and RAM contain the more specific data to display the results of the calculation.



Choices that can be made are:

General

Graph Properties

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

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.

Note that, if the RAM module is installed, always the

	attributes Ammonium, Nitrate and Phosphor are displayed. These attributes are standard quality variables in RAM
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 <i>Note that only boundary conditions are presented by making selections on the tab General!</i> 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 corresponds with the order of the data types list.
Dufflow	
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 Boundary file (*.BND), Quality Boundary file (*.BNK), Flow Results file (*.RES) or Quality Results file (*.REK) to display these boundaries or results in the same graph. DMS will open the Measured Data dialog box.
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	Choose the type of objects: Sections or Nodes. 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 If no Sections or Nodes are displayed, the calculation is not completed.
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 corresponds with the order of the data types list.
RAM	
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

Objects to display

to show.

Choose the type of objects: Areas or checked Areas.

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 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 corresponds with the order of the data types list.

Related topics:

New Time Graph Window

New Text Window

Change Graph Contents

Graph Window Properties

9.3.5 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. After the selection of the data, which should be displayed, DMS will open a New Space Related Graph window. The Space Related Graph window always appears in the Workspace.

Command:

Menu bar: View – New Space Graph Window...


Context menu: In the Scenario Manager window after the selection of a scenario - New Space Graph Window...

Toolbar: 


Tip

To move quickly in time through a Space Related Graph, place the cursor on a part of the date/time field below the Graph, then use the Up or 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.

When a New Space Related Graph is opened, the results of the first time step are presented. In the Space Related Graph window a date-field and arrow-buttons are available to move through the calculation period in time. These buttons are also available on the Time Control toolbar.

Use the  button (Start the timer) to display the results in time like a movie.

The time step size and the delay between two film shots can be defined with the

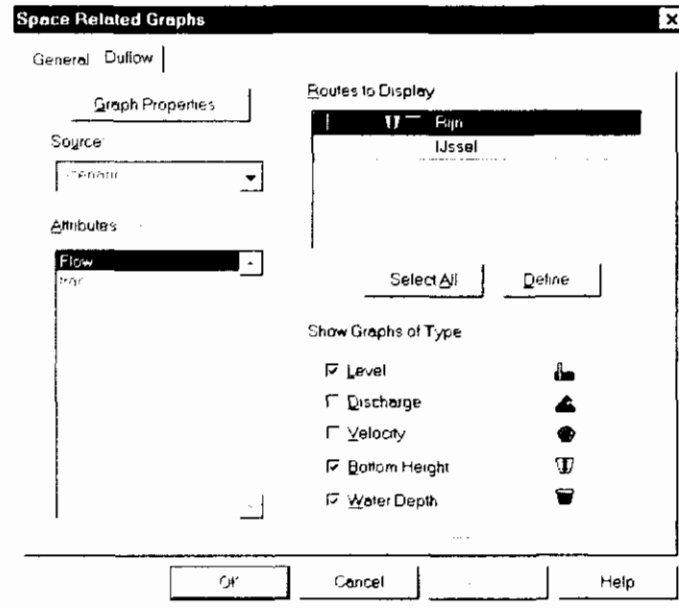
 button (Configure the timer).

Related topics:

Graph windows
 Space Related Graph dialog box
 Time Control toolbar

9.3.6 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:

General

Show vertical lines at section breaks

DMS shows vertical lines at sections breaks on the route of the Space Graph. This option makes the position on the route visible

DufLOW

Graph Properties

DMS will open the Graph Properties dialog box. For more information see the Graph Window Properties 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 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 corresponds with the order of the graph types list.

Related topics:

New Space Graph Window

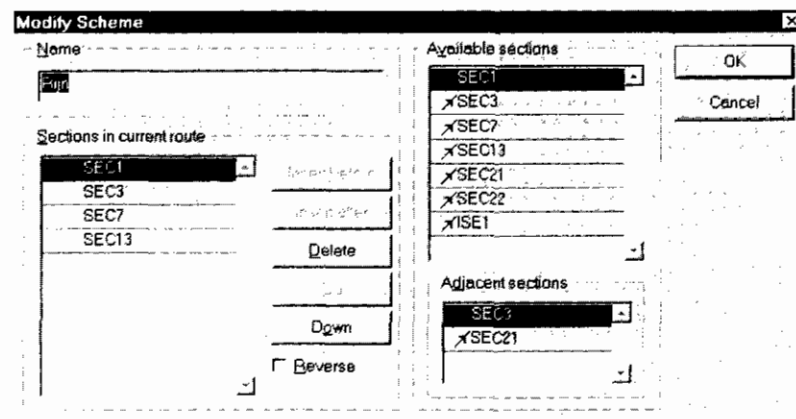
Graph Window Properties

Change Graph Contents

Modify Route dialog box

9.3.7 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

9.3.8 Change Graph Contents

Use this command to reset the display options per source and per object. After selecting the command DMS will show the Time Related Graph or Space Related Graph dialog box. The options in the dialog box are explained in the Time Related Graph or Space Related Graph dialog box.

Command:

Menu bar: Edit – Graphs/Table...

Context menu: In the Graphs window - Graphs...

Related topics:

Time Related Graph dialog box

Space Related Graph dialog box

9.4 Customizing Graph window

DMS offers the following commands to move through and customize Graph windows:

- Hairline mode
- Zooming in and Zooming out
- Graph Window Properties

9.4.1 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:

Context menu: In the Graph window - Hairline mode

Toolbar: 

9.4.2 Zooming Tool (Graph window)

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:

Context menu: In the Graph window - Zoom mode

Toolbar: 

Related topics:

Zooming out

9.4.3 Zooming out (Graph window)

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:

Context menu: In the Graph window - Zoom out

Toolbar: 

Related topics:

Zooming tool

9.4.4 Graph Window Properties

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

The Graph Window 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 bar: Edit – Window Properties...

Context menu: In the Graph window - Properties...

Toolbar: 

Related topics:

Change Colors

9.4.5 Change Colors

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

Command:

Menu bar: Edit - Colors...

Context menu: In the Graphs window - Colors...

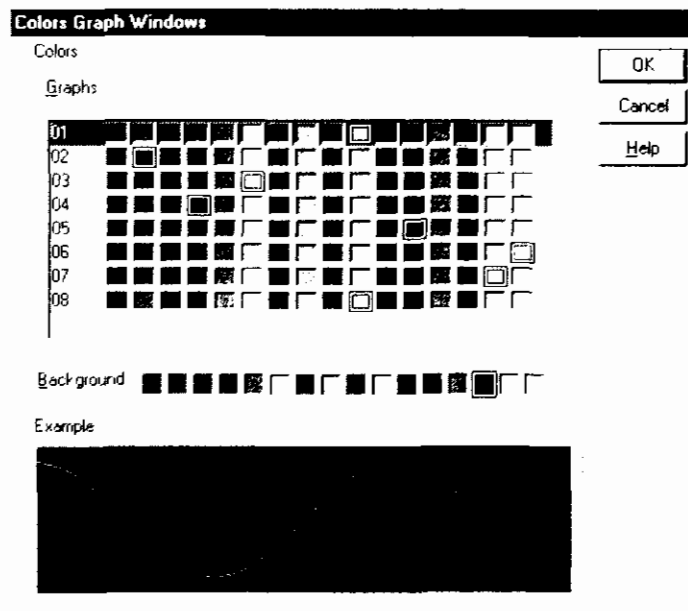
Related topics:

Colors Graph Window dialog box

Graph Window Properties

9.4.6 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. |

Related topics:

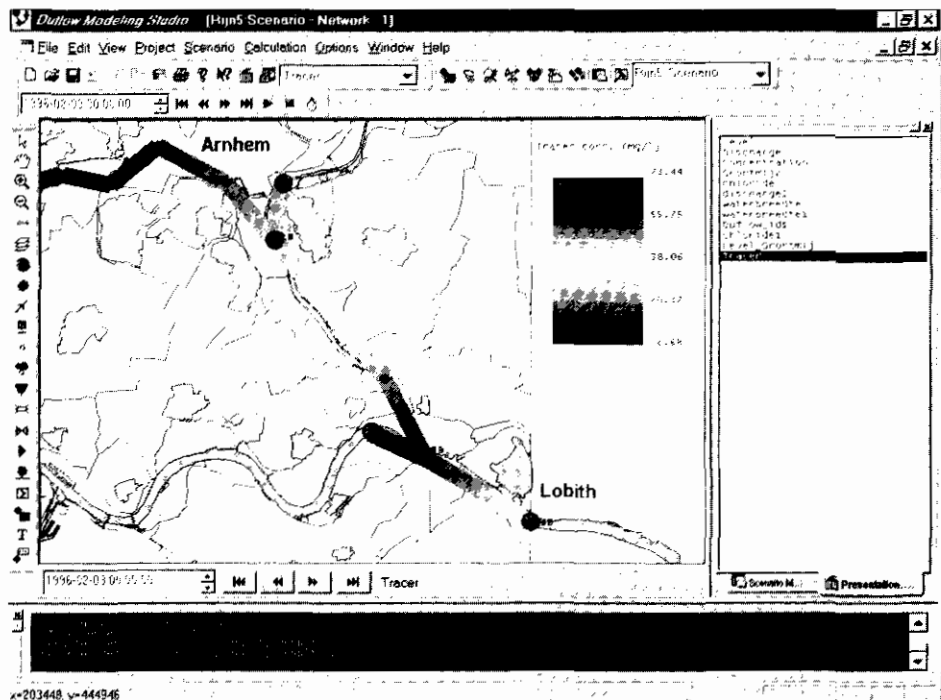
Change Colors

9.5 Network Window in Presentation Mode

For some years Dufflow is able to show the results of computations in tables and graphs. The introduction of Dufflow for Windows and its ability to visual edit the network have made it possible to show the computation results in the network window. The network's presentation depends on the calculation results for a given point in time.

The Presentation mode supports the DMS user by making decisions in water management. Because of the amount of possibilities the decision has been made to make the Presentation mode programmable. When a network is presented in Presentation mode, before any element is drawn a script will be executed. The results of this script determine the presentation of the network. If no script is defined the network is shown in its usual appearance.



The script to be executed differs per object type. If for example you do not want to show the cross sections in presentation mode, you include the "hide" command in the script.



9.5.1 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. If a Presentation Script is not directly chosen, DMS will open the Select Presentation Script Scheme dialog box. After the selection of a Presentation Script, DMS will redraw the Network window according to the presentation script with the results of the first time step. In the Network window a date-field and arrow-buttons are available to move

through the calculation period in time. These buttons are also available on the Time Control toolbar.

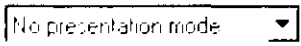

Use the  button (Start the timer) to display the results in time like a movie. The time step size and the delay between two film shots can be defined with the  button (Configure the timer).

Use this command after a calculation is made.

Command:

Menu bar: Edit - Presentation Mode

Context menu: In the Network window - Presentation mode

Toolbar:  or 

If no Presentation scripts are available for selection, make sure that the right directory for Presentation scripts is set. This can be done by using the Program Settings command.

Related topics:

Presentation Scripts

Presentation Scripts dialog box

Program Settings

Time Control toolbar

9.5.2 Presentation Scripts (command)

Use this command to modify the Presentation Scripts. DMS will open the Select Presentation Script Scheme dialog box. If no Presentation scripts are available for selection, make sure that the right directory for Presentation scripts is set. This can be done by using the Program Settings command.

After the selection of a Presentation Script scheme you can add, modify, delete or copy a Presentation Script in the Presentation Script dialog box.

Command:

Menu bar: Edit - Presentation Scripts...

Context menu: In the Workspace Manager window after the selection of a script - Modify...

Toolbar: 

To modify a Presentation Script is also possible to open a Presentation Script window in the Workspace with the contents of the Presentation Script.

Command:

Context menu: In the Workspace Manager window after the selection of a script - Edit...

Double click: In the Workspace Manager window on a script

Toolbar: 

Related topics:

Presentation Script dialog box / window

Program Settings

9.5.3 Presentation Script dialog box / window

In the Presentation Script dialog box or window you can 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 Duflow Reference Manual.

Related topics:

Presentation Scripts
Creating Presentation Scripts
Presentation Script Examples

9.5.4 Creating Presentation Scripts

A Presentation Scripts is created by giving values to the attributes of Network objects. A value can be a color. In that way colors can represent a certain values or ranges of an output variable. Also functions and expressions can be used to define the values. A special part of a Presentation Script is the definition of the Legend.

In this paragraph the following is described:

- Attributes of the Network objects.
- Attributes of the Legend
- Attributes of the Presentation
- Values for colors
- Functions and Expressions, which can be used to assign values to the attributes of the Network objects

Related topics:

Presentation Scripts
Presentation Script Examples

9.5.4.1 Attributes of Network objects

All variables of function prefixed with **d_** are only available when the Duflow component is available.

All objects

The following attributes are available for all objects:

Attribute	Description
Id	ID of the object, e.g. NOD00001
Name	Name of the object, e.g. Rhine
Color	Color of the object.
Label	The label of the object.: e.g. label=id label='reference node' label=d_level(t) - for object of type section only
Hide	Hides the object

Sections

The following attributes are available:

Attribute	Description
Colorwidth	Width that DMS uses to calculate the radiant of colors.
Legendcolor	If called DMS will base it's legend on the variable given for d_color
d_color	The color of the section
d_concentration	The concentration of a quality variable at a certain point in time
d_discharge	The discharge at a certain point in time
d_floorheight	The floor level as given in the cross section. <u>at a certain point in time</u>
d_flowwidth	The flowwidth at a certain point in time for d_level(t)
d_level	The level at a certain point in time
d_load	The load of a quality variable at a certain point in time
d_maxwidth	The maximum width at a certain point in time for d_level(t)
d_text	A label at the beginning of the section
d_velocity	The velocity at a certain point in time
d_waterdepth	The waterdepth at a certain point in time. This is calculated by: $d_waterdepth(t) = d_level(t) - d_floorheight$
d_width	The width of the section in pixels

Nodes, Schematization points and Calculation points

The following attributes are available:

Attribute	Description
d_id	The ID used by the DufLOW calculation engine.

Structures

The following attributes are available:

Attribute	Description
d_concentration_begin	The concentration of a quality variable at a certain point in time at the begin of the structure.
d_concentration_end	The concentration of a quality variable at a certain point in time at the end of the structure.

d_discharge_begin	The discharge at a certain point in time at the begin of the structure.
d_discharge_end	The discharge at a certain point in time at the end of the structure.
d_level_begin	The level at a certain point in time at the begin of the structure.
d_level_end	The level variable at a certain point in time at the end of the structure.
d_load_begin	The load of a quality variable at a certain point in time at the begin of the structure.
d_load_end	The load of a quality variable at a certain point in time at the end of the structure.
d_id	The id used by the DufLOW calculation engine.

9.5.4.2 Attributes of the Legend

The following attributes are available:

Attribute	Description
Autocolor	DMS uses the minimum and maximum values of the first variable set for script type section to calculate the values for d_color. The colors generated are light blue, light green, yellow, light red and light magenta. Do not use simultaneously with the <i>legend</i> attribute.
Autovalue	DMS scales the values set with the <i>legend</i> attribute to the min and max values of the variable set for d_color.
Hide	Hides the legend
Legend	Legend(value, color) Function to set a color in the legend. Examples: <code>legend (0, red)</code> <code>legend (0, rgb (255, 0, 0))</code> Do not use simultaneously with the <i>autocolor</i> attribute.
Roundoff	Idem as autocolor. The values for the colors are scaled to the minimum and maximum values of the first variable set for script type section.
Smooth	DMS will try to draw a smooth legend by rendering colors for missing values
Title	The title shown above the colors of the legend.

In addition to these attributes for the Legend, a attribute LegendColor is available for the Section object script. If this function is called DMS will link its legend to the first variable it encounters in the section script. See the special examples in the example section.

9.5.4.3 Attributes of the Presentation

The following attributes are available:

Attribute	Description
Redraw	Call this function if you want DufLOW to redraw the entire network for every time step. This can be useful for scripts that change the width of a section.

9.5.4.4 Colors

Colors are referenced in the scripts by using RGB values. A number of colors is predefined:

Color	Definition
Black	RGB(0,0,0)
Blue	RGB(0,0,128)
Brown	RGB(128,128,0)
Cyan	RGB(0,128,128)
Gray	RGB(128,128,0)
Green	RGB(0,128,0)
Lblue	RGB(0,0,255)
Lcyan	RGB(0,255,255)
Lgray	RGB(192,192,192)
Lgreen	RGB(0,255,0)
Lmagenta	RGB(255,0,255)
Lred	RGB(255,0,0)
Magenta	RGB(128,0,128)
Red	RGB(128,0,0)
White	RGB(255,255,255)
Yellow	RGB(255,255,0)

9.5.4.5 Functions and Expressions

Function	Description	Example
abs	The abs function calculates the absolute value.	label=abs(d_level(t))
and	The logical 'and' operation.	if (d_level(t)>1) and (d_level(t)<2) then ... endif
or	The logical 'or' operation.	if (d_level(t)<1) or (d_level(t)>2) then ... endif
if	The if statement allows you to change the flow of control. Syntax: if (<i>condition</i>) then [<i>statement</i>] else [<i>statement</i>] endif	if (d_level(t)>1) then color=red else color=blue endif

9.5.5 Presentation Script Examples

The following examples will clarify the use of the Presentation Mode. All the examples assume the Dufflow component is available.

9.5.5.1 Complete Examples

example 1

If we take the DMS demo project and would like to show the water level of the river. We have to take the following steps:

1. Choose Edit - Presentation Scripts
In the dialog Select Presentation Script Scheme click on the Add button.
Name it "demoLevel"
Select in the Object Types listbox *sections* and type in the following script:

```
d_width=10  
d_color=d_level(t)  
legendcolor
```

d_width means the width of a section is always 10 pixels. d_color means the color is dependent on the water level.
The variable t in d_level indicates time. This means that the color is dependent on the water level at a certain point in time. Besides t (time) in some cases a quality variable can be included as a parameter; for instance d_concentration(t, 'salt').
Select in the Object Types listbox *legend* and type in the following script:

```
autocolor  
smooth
```

Autocolor means the legend will use a standard color palette.
Smooth indicates the legend will try to draw a smooth legend by rendering colors for missing values.
2. Choose OK and OK
3. Open the Network window and ensure that the corresponding Flow model is calculated correctly.
4. Choose Edit - Presentation Mode
5. Select the script "demoLevel"
DufLOW will now redraw the Network in Presentation Mode. At the bottom of the Network window a number of buttons appear together with a time indicator. With these buttons we can show the status of the network at another point in time.
6. DufLOW determines the range of the variables used in the script based on the results in the resultfile. With this range a color legend and which color corresponds to which value is determined.

example 2

For this example we use a network with a number of pumps. If the water level reaches a certain level the pump switches on and causes a discharge. The funny thing is that we can use relatively simple script to test whether DufLOW is working properly. Suppose we want a pump to start at a water level of 10. We can visualize this by using the following script for pumping engines:

```
if (d_discharge_begin(t) > 0) then  
label='on'  
else  
label='off'  
endif  
if (d_level_begin(t) > 10) then  
color=lred  
else  
color=lblue  
endif
```

Now when we turn the presentation mode timer on and the color of the pump turns red, the accompanying text changes from off to on.

Duflow determines the colors of the legend based on the first variable it encounters in "section"-script. This means the result is influenced by the order of the commands in the script. For instance if you want to make the width of the section dependent on the floor height and the water level dependent on the color, then the next script will meet your expectations.

right: `d_color=d_level(t)`
`d_width=d_floorheight(t)`

When you change the order of the commands the output is not what you expected. Duflow determines the legend based on the floor height and the colors in the presentation mode are presented wrongly: so

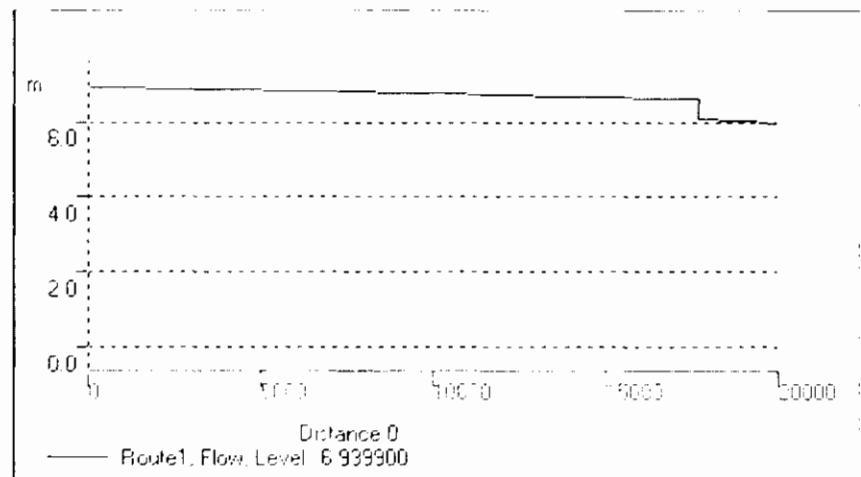
wrong: `d_width=d_floorheight(t)`
`d_color=d_level(t)`

9.5.5.2 Legend Examples

For the first set of 5 examples the script for type object Section is always

```
d_width=10
d_color=d_level(t)
legend.dcolor
```

and the minimum level is 6 metres and the maximum level is 7.11 metres. The space-oriented graph of time step 1 is:



The weir causes the jump in the graph.

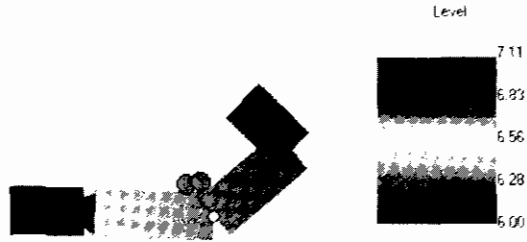
Example 1

Autocolor



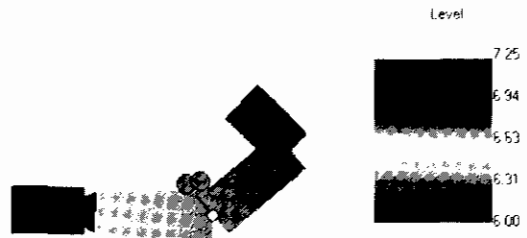
Example 2

```
Autocolor
Smooth
```



Example 3

```
Autocolor
Smooth
Roundoff
```



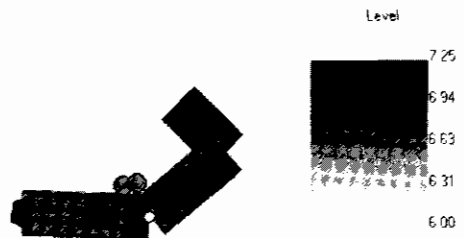
Example 4

```
Smooth
Roundoff
legend(0, yellow)
legend(1, magenta)
```



Example 5

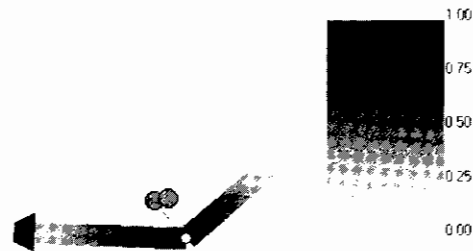
```
Smooth
Roundoff
legend(0, yellow)
legend(1, magenta)
autovalue
```



If we are interested in special values we have to do a little more programming. Say the values in the range [6.65, 6.75] are of particular interest. We could then use the following script:

Example 6A

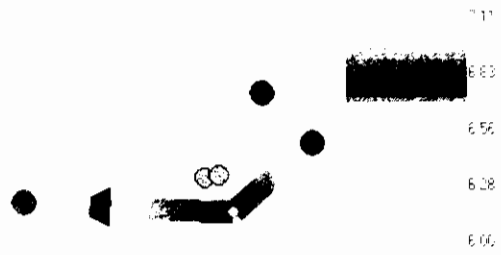
```
[section]
d_width=10
d_color=lgray
if (d_level(t) >= 6.65) then
  d_color=lred
endif
if (d_level(t) > 6.75) then
  d_color=yellow
endif
```



Example 6B

But showing the right legend becomes a problem

```
[legend]
legend(6, lgray)
legend(6.65, lgray)
legend(6.75, lred)
legend(7.11, yellow)
smooth
```

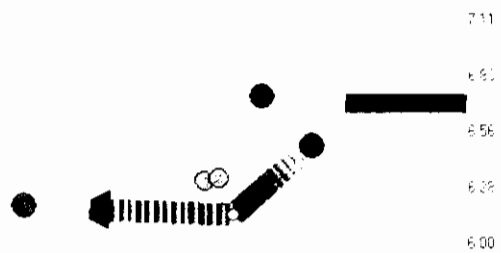


Example 6C

in the case of an discrete legend

```
[legend]
legend(6, lgray)
legend(6.65, lgray)
legend(6.75, lred)
legend(7.11, yellow)
```

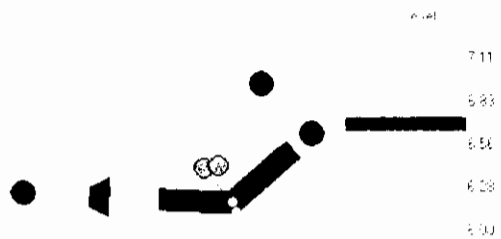
The strange colors are caused because DMS tries to



Example 6D

Much simpler is letting the legend do the work:

```
[section]
d_width = 10
d_colored_level(t)
LegendColor
```



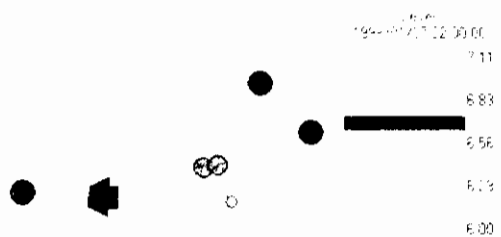
Example 7

Now we want to make visible when the level at the beginning of the weir reaches a certain level:

```
[weirs]
color = white
if (d_level_begin(t) >= 6.725)
then
  color = lred
endif
```



and

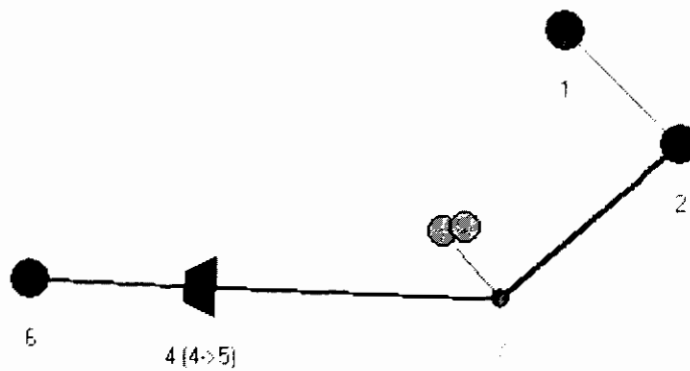


9.5.5.3 Sample Scripts

Duflow IDs

The purpose of this script is to show the DufLOW IDs as used by the calculation engine. These numbers can also be found in the *.NET, *.BND, *.RES and alike files.

Object type	Script
Sections	d_width=1
Nodes	label=d_id
Cross Sections	hide
Calculation points	label=d_id color=gray
Schematization points	label=d_id color=brown
Discharge points	
Culverts	label=d_id color=green
Pumping engines	label=d_id
Siphons	label=d_id color=brown
Structure extended	label=d_id color=cyan
Weirs	label=d_id color=red
Areas	
Presentation	
Legend	



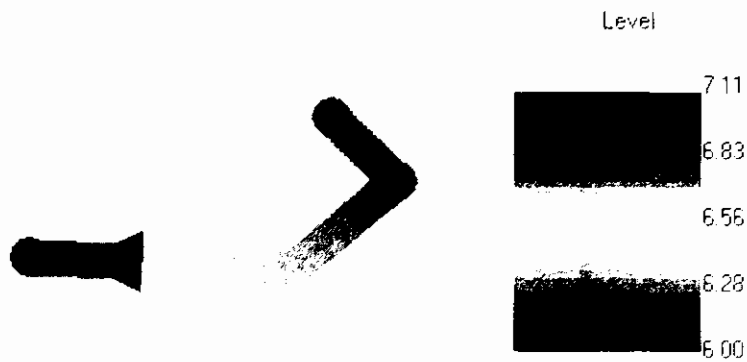
The effects of the DufLOW_ids script

Level

The purpose of this script is to represent the level.

Object type	Script
Sections	d_width=20 d_color=d_level(t) legende_color
Nodes	
Cross Sections	Hide
Calculation points	Hide

Schematization points	Hide
Discharge points	
Culverts	
Pumping engines	
Siphons	
Structure extended	
Weirs	
Areas	Hide
Presentation	
Legend	autocolor smooth



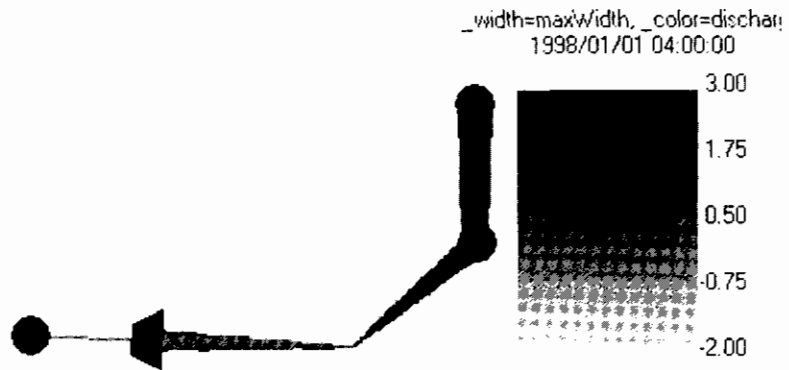
The effects of the level script

Maximum Width

In this script the width of the sections depends on the maximum width of the section. DMS uses both the cross section and level(*t*) to calculate the actual width.

Object type	Script
Sections	d_color=d_discharge(t) d_width=d_maxwidth(t) LegendColor
Nodes	
Cross Sections	Hide
Calculation points	Hide
Schematization points	Hide
Discharge points	
Culverts	
Pumping engines	
Siphons	
Structure extended	
Weirs	
Areas	Hide
Presentation	redraw
Legend	'Title=', width=maxWidth, , color=discharge' smooth autovalue

```
legend(0, lGray)  
legend(1, magenta)  
roundoff
```



The effects of the MaxWidth script

N.B. A modified demo project was used for these results.

10. 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 starting a Duflow computation.

Calculation point

Duflow generates calculation points when the length of a section exceeds the defined maximum length. Calculation points divide a DMS section in Duflow sections equal or smaller then this maximum length.

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 is 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.

Duflow files

Internal ASCII files, which can be read by the executable CDuflow.exe. CDuflow.exe performs the Duflow calculation.

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.

External variables

External variables, which are space and/or time dependent and used in the quality process equations in the Quality Model description file.

General Structure

Structures that 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 starting 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 draw interactively 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.

Parameters

Parameters, constants and coefficients used in the quality process equations in the Quality Model description file.

Presentation Mode

Mode of the Network window in which the results of a calculation are spatially visualised.

Presentation Script

Definition of the presentation of Network objects in the Presentation Mode.

Pump

Pumping station in or near a waterway.

Quality Model description file

File in which the relevant quality processes are described. A Quality Model description file is an ASCII-file with the extension MOD.

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.

Shape file

File in a pre-defined format, which represents a certain geographic theme. Shape files can be save in a group in a VSF-file. Only Shape-files can be used as a map layer in DMS.

Siphon

A circular pipe used to carry water over obstacles.

SUF

Standard Exchange Format (Dutch: Standaard Uitwisselings Formaat); Standard data model for the schematization of surface water systems.

Time series

A series of values for a time dependent variable or parameter. Time series are stored in a scheme.

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 water surface.



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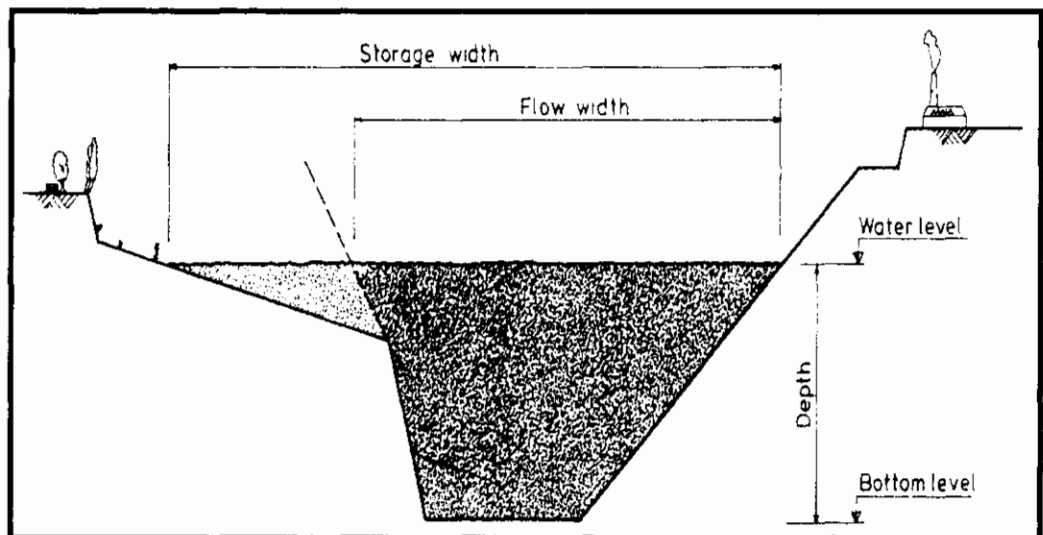
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Duflow

Reference Manual

VERSION 3.3 April 2000

Stowa / EDS



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Appendices

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B. Eutrof 2

1. Introduction

1.1 In 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 ICM). 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: MODFLOW, 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 the DUFLOW MODELLING STUDIO (DMS). In DMS the RAM component is integrated with the DUFLOW component. In the future also MODFLOW 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 DUPRO1 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.

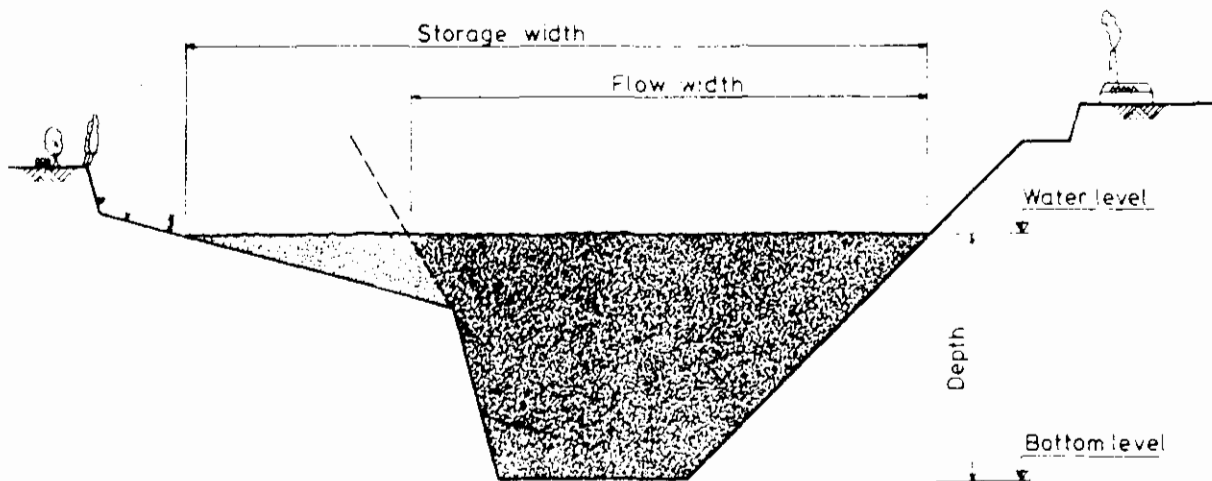


Figure 1.1 Cross sectional distribution

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.

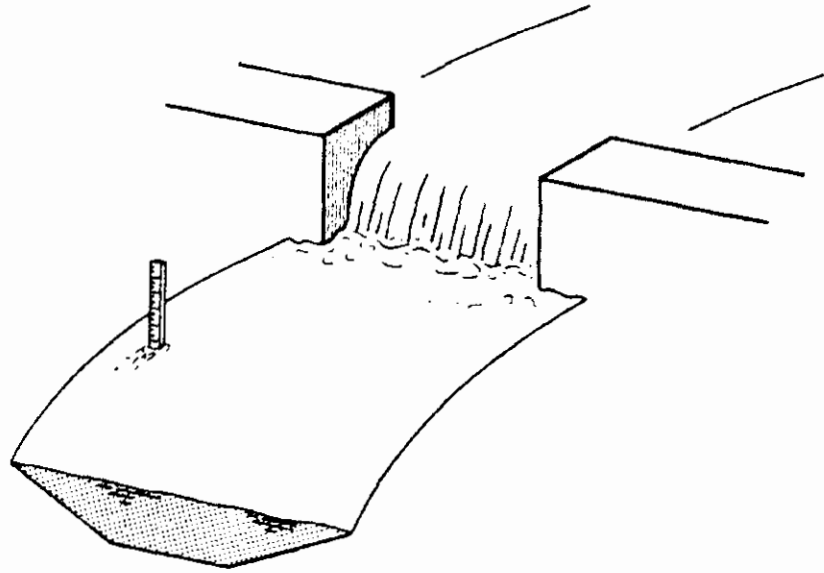


Figure 1.2 Sketch of a hydraulic structure.

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 3.3)
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-, 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:

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

and

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

while the relation:

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

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 [$m^{1/2}/s$]
$w(t)$	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:

$$\alpha = \frac{A}{Q^2} \int v^3(y, z) dy dz$$

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:

$$\frac{\partial(\alpha Qv)}{\partial x} \quad (4a)$$

can be broken into

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

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:

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

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

and

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

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.

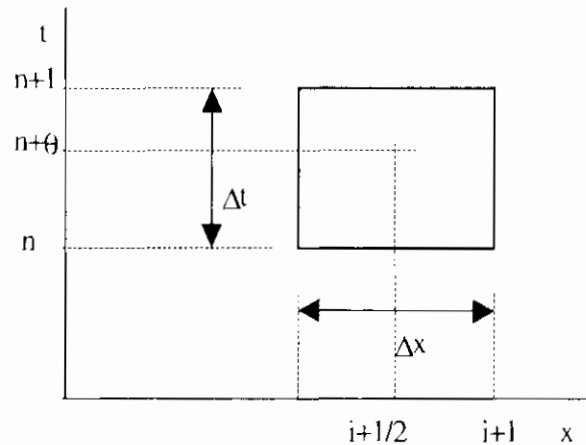


Figure 2.1

The Four Point Preissmann scheme

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

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

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

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

equation (1) is transformed into:

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

and equation (2) into:

$$\begin{aligned} \frac{Q_{i,t}^{n+1} - Q_{i,t}^n}{\Delta t} + gA_{i,t} (H_{i,t}^{n+\theta} - H_{i,t}^{n-\theta}) + \alpha \left(\frac{Q_{i,t}^{n+1} - Q_{i,t}^n}{\Delta x} - \frac{Q_{i,t}^n - Q_{i,t}^{n-1}}{\Delta x} \right) + \\ + \frac{g(Q_{i,t}^{n+1} | Q_{i,t}^n)}{(CAR)_{i,t}} - a' \gamma (w_{i,t}^{n+1}) \cos(\Phi^{n+1} - \theta) \end{aligned} \quad (8)$$

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 θ (like in $A_{i,t}^{n+\theta}$) expresses that these values are approximated at time $t^{n+\theta}$. This discretization is of second order in time and place if the value $\theta = 0.5$ 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:

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

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

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} :

$$Q_{1,t}^{n+1} = N_{11} H_{1,t}^{n+1} + N_{12} H_{2,t}^{n+1} + N_{13} \quad (9a)$$

$$Q_{2,t}^{n+1} = N_{21} H_{1,t}^{n+1} + N_{22} H_{2,t}^{n+1} + N_{23} \quad (9b)$$

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:

$$\sum_{i=1}^H Q_{i,t} + q_t = 0 \quad (10)$$

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

2.2.4.2 Weirs

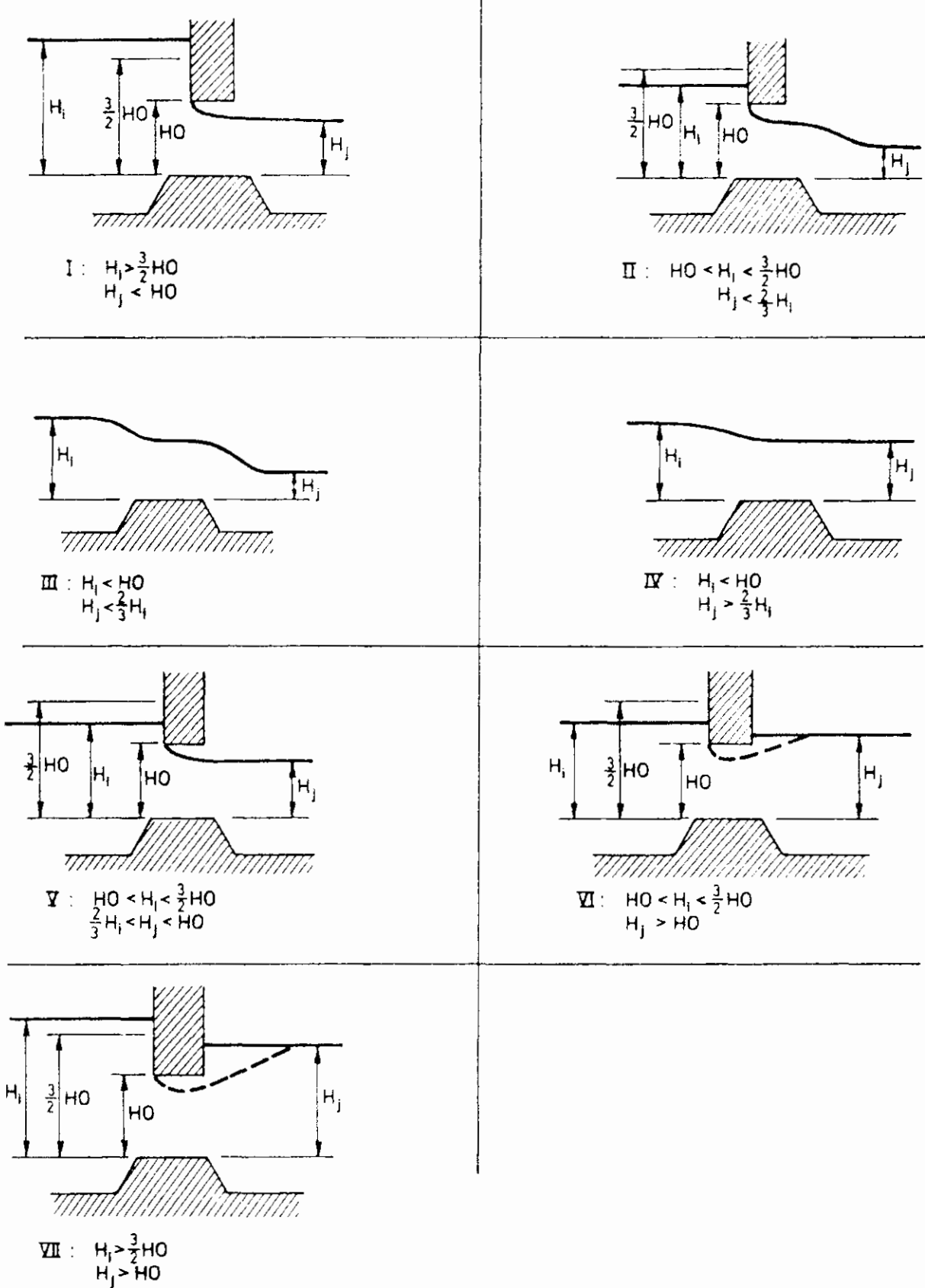


Figure 2.2 Weir flow conditions - covered by DUFLOW

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

$$Q^{n+1} = \mu B H \sqrt{2g \Delta H} \quad (11)$$

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.

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

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:

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

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:

$$Q = AC \sqrt{R \frac{\Delta H}{L}} \quad (14)$$

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:

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

or

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

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

$$Q^{n+1} = F (H_i^{n+1} - H_I^{n+1}),$$

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

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

H_I 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:

$$Q^{n+1} = N_1' H_i^{n+1} + N_2' H_j^{n+1} + N_3' \quad (15)$$

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 .

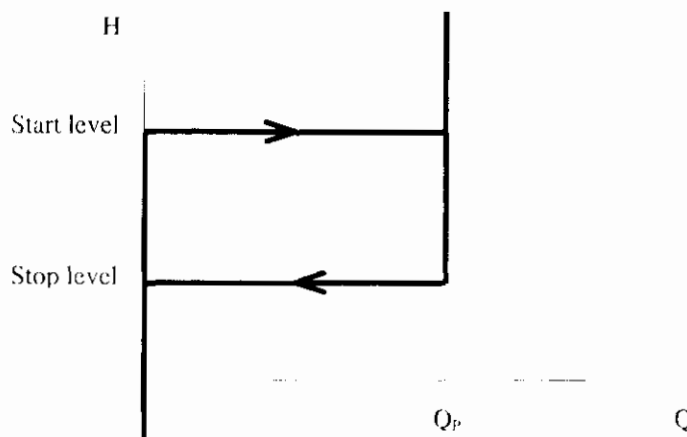


Figure 2.4 Dependence of drainage pump operation on upstream water level

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.

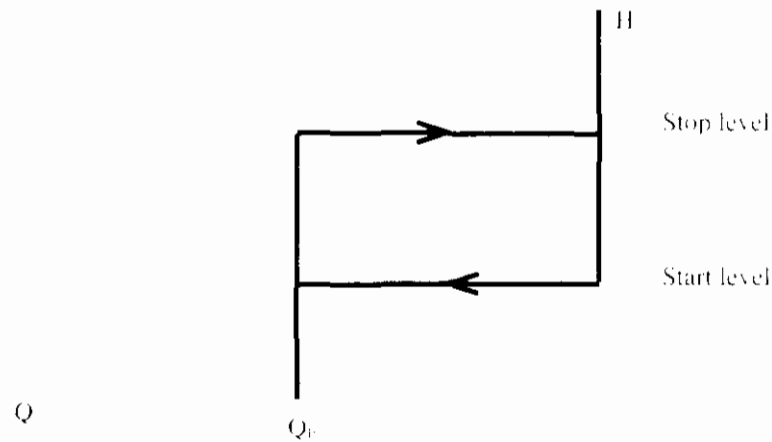


Figure 2.5 Dependence of supply pump operation on upstream water level

2.2.4.6 Gap growth structure (not available in DMS 3.3)

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:

$$H(t) = \begin{cases} H_0 - (H_0 - H_{max}) \sqrt{\frac{(t - T_{start}) T_{h_{max}}}{T_{h_{max}}}} & \text{for } t < T_{start} + T_{h_{max}} \\ H_0 & \text{for } t < T_{start} \\ H_{max} & \text{for } t > T_{start} + T_{h_{max}} \end{cases}$$

$$B(t) = \begin{cases} B_0 + (B_{max} - B_0) \sqrt{\frac{(t - T_{start}) T_{b_{max}}}{T_{b_{max}}}} & \text{for } t < T_{start} + T_{b_{max}} \\ B_0 & \text{for } t < T_{start} \\ B_{max} & \text{for } t > T_{start} + T_{b_{max}} \end{cases}$$

With

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

B_0 initial width of the gap [m]

- B_{max} maximal width of the gap [m]
- $H(t)$ gap height at time t [m]
- H_{in} 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.

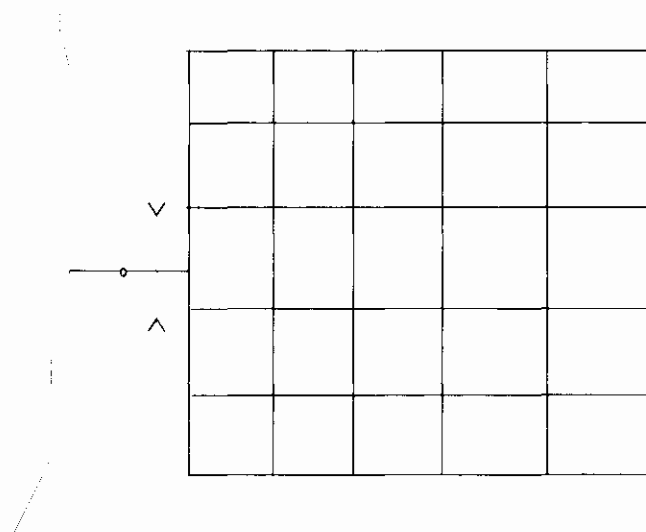


Figure 2.6 Schematization of model for simulation a dike burst

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 system¹ 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.

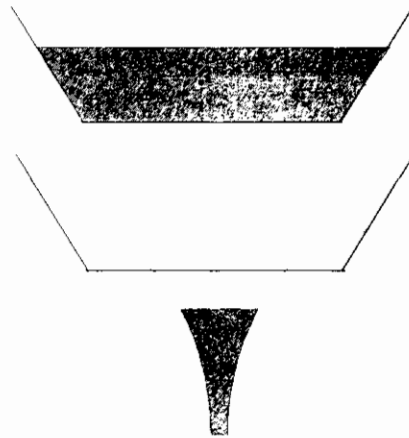


Figure 2.7 The Dry flood procedure

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.

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

where:

- C constituent concentration [g/m^3]
- Q flow [m^3/s]
- A cross-sectional flow area [m^2]
- D dispersion coefficient [m^2/s]
- B cross-sectional storage area [m^2]
- 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:

$$\frac{\partial S}{\partial x} + \frac{\partial (BC)}{\partial t} - P = 0 \quad (17)$$

in which S is the transport (quantity of the constituent passing a cross-section per unit of time):

$$S = QC - \Lambda D \frac{\partial C}{\partial x} \quad (18)$$

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.

The dispersion coefficient either can be supplied by the user or can be calculated from the characteristics of the flow. The empirical equation according to Fisher (1979) is used to calculate the flow dependent part. In order to prevent the dispersion coefficient to become 0 at low flow velocities a constant term is added that reflects background dispersion. The flow independent part is in particular important in stagnant systems, where it represents the wind induced mixing. The following equation is used:

$$D(x, t) = \alpha_s \cdot \frac{u_s^2 \cdot W^2}{Z \cdot u_*} + D_0 \quad (19)$$

where:

α_s a proportionality constant [-]

W flow width [m]

u_s average flow over the cross-sectional area [m/s]

Z water depth [m]

u_* shear stress velocity [m/s]

D_0 background dispersion coefficient [m²/s]

The shear stress u_* can be written as:

$$u_* = u_s \cdot \frac{\sqrt{g}}{C} \quad (20)$$

where:

C coefficient of De Chézy [m^{1/2}/s]

g acceleration due to gravity [m²/s]

Substitution of eq. (20) into (21) leads to:

$$D(x,t) = \alpha_c \frac{|u \cdot B \cdot C|}{Z \cdot \sqrt{g}} + D_0 \quad (21)$$

As all the characteristics of the flow are known or calculated in the flow part, eq. (21) easily can be used to calculate the dispersion coefficient. Only α_c and D_0 have to be supplied by the user. In case α_c equals 0, $D(x,t) = D_0$. In that case dispersion will be modelled as independent of the flow.

As both D_0 and α_c are external variables, both can vary in time and space. Typically for river systems values for α_c of 0.011 (Fisher, 1979) are used. For smooth canal systems values of 0.001 have been reported and van Mazijk (1996) found values in the order of magnitude of 0.02 for River Rhine stretches where the mixing is influenced by dead zones behind groynes.

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 :

$$\int_0^{\Delta x} \psi_i \left[\frac{\partial S_i}{\partial x} + \frac{\partial (BC)}{\partial t} - P_i \right] dx = 0 \quad (19)$$

results into:

$$\psi_i S_{i,0} + \int_0^{\Delta x} \psi_i \left[\frac{\partial (BC)}{\partial t} - \frac{\partial \psi_i}{\partial x} \left(QC - A_i D \frac{\partial C}{\partial x} \right) - \psi_i P_i \right] dx = 0 \quad (20)$$

In each section we distinguish two weighting functions:

$$\psi_1 = 1 - \frac{x}{\Delta x} \quad (21)$$

$$\psi_2 = \frac{x}{\Delta x} \quad (22)$$

C is assumed to vary linearly within the section Δx , i.e.:

$$C = \psi_1 c_1 + \psi_2 c_2 \quad (23)$$

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:

$$-S_1 + \frac{\Delta x}{3} \frac{\partial B_1 c_1}{\partial t} + \frac{\Delta x}{6} \frac{\partial B_2 c_2}{\partial t} + \frac{Q_1 c_1 + Q_2 c_2}{2} - A_1 D \frac{c_2 - c_1}{\Delta x} +$$

$$-\frac{\Delta x}{3} P_1 - \frac{\Delta x}{6} P_2 = 0 \quad (24)$$

$$+S_2 + \frac{\Delta x}{6} \frac{\partial B_1 c_1}{\partial t} + \frac{\Delta x}{3} \frac{\partial B_2 c_2}{\partial t} - \frac{Q_1 c_1 + Q_2 c_2}{2} + A_2 D \frac{c_2 - c_1}{\Delta x} +$$

$$-\frac{\Delta x}{6} P_1 - \frac{\Delta x}{3} P_2 = 0 \quad (25)$$

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:

$$S_1^- = -\frac{(1-\theta)}{\theta} S_1^- + \frac{\Delta x}{3\theta} \left(\frac{B_1^+ c_1^- - B_1^- c_1^-}{\Delta t} \right) + \frac{\Delta x}{6\theta} \left(\frac{B_2^+ c_2^- - B_2^- c_2^-}{\Delta t} \right) +$$

$$+ \frac{\theta Q_1^- c_1^+ + \theta Q_2^- c_2^+ + (1-\theta) Q_1^- c_1^- + (1-\theta) Q_2^- c_2^-}{2\theta} + \quad (26)$$

$$- A_1 D \frac{\theta c_2^+ - \theta c_1^- + (1-\theta) c_2^- - (1-\theta) c_1^-}{\Delta x \theta} - \frac{\Delta x}{3\theta} P_1 - \frac{\Delta x}{6\theta} P_2$$

$$S_2^- = -\frac{(1-\theta)}{\theta} S_2^- - \frac{\Delta x}{6\theta} \left(\frac{B_1^+ c_1^- - B_1^- c_1^-}{\Delta t} \right) - \frac{\Delta x}{3\theta} \left(\frac{B_2^+ c_2^- - B_2^- c_2^-}{\Delta t} \right) +$$

$$+ \frac{\theta Q_1^+ c_1^- + \theta Q_2^+ c_2^- + (1-\theta) Q_1^+ c_1^- + (1-\theta) Q_2^+ c_2^-}{2\theta} + \quad (27)$$

$$- A_2 D \frac{\theta c_2^+ - \theta c_1^- + (1-\theta) c_2^- - (1-\theta) c_1^-}{\Delta x \theta} + \frac{\Delta x}{6\theta} P_1 + \frac{\Delta x}{3\theta} P_2$$

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 $\theta = 1$ 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 F on the left hand side, the coefficients N_{13} and N_{23} appear in the right hand side (F):

$$\begin{array}{c}
 i \quad j \\
 \left(\begin{array}{cc}
 * & * \\
 * & *
 \end{array} \right) \cdot \left(\begin{array}{c}
 * \\
 *
 \end{array} \right) = \left(\begin{array}{c}
 * \\
 *
 \end{array} \right) \\
 E \quad \bullet \quad C = F
 \end{array}$$

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

$$* \quad 1 \quad \text{section } i \quad 2 \quad \text{node } j$$

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

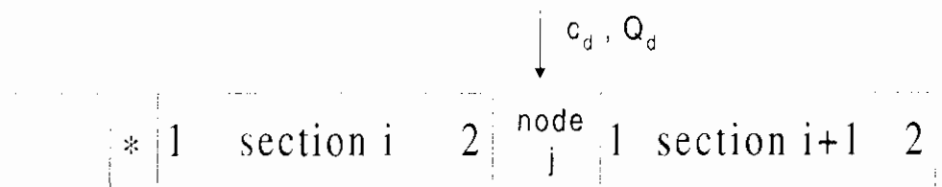
- If a C-boundary is defined at node j, without using an H or Q boundary. The specified concentration c_b is substituted in equation (27).

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
 $S_{1,i+1} = Q_{1,i+1} c_{1,i+1}$ 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 every defined dissolved substance or define no 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. An exception to this concept is the mass transfer of gasses and volatile substances at weirs, general structures and culverts. At these structures the effect of additional mass transfer can be modelled. Although the concept was originally introduced to simulate the enhanced oxygen transfer at weirs, it also can be used to describe the release of volatile substances.

$$* \quad 1 \quad \text{section } i \quad 2 \quad * \quad \overset{\text{structure}}{Q_s} \quad * \quad 1 \quad \text{section } i+1 \quad 2$$

If flow is from i to $i+1$: $S_1 = S_2 = Q \cdot c_{i+1}$

If flow is from $i+1$ to i : $S_1 = S_2 = Q \cdot c_{i,i+1}$

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 DUFPROL. 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

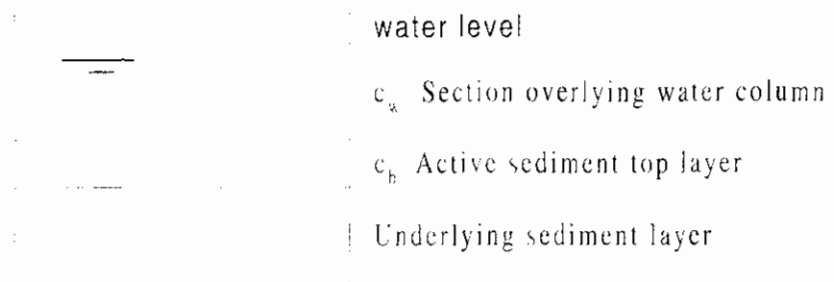
descriptions or define a new set of descriptions without changing and recompiling the source code of the calculation part of DUFLOW. A full explanation of the syntax of the language and the use of DUPRO1 is given in Chapter 3.

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:

$$F_{ex} = \frac{E_{ex}}{H_b} \left(c_a - \frac{c_b}{por} \right)$$

where:

- F_{ex} the exchange flux between water and sediment [$g/m^2 \cdot day$]
- E_{ex} diffusive exchange rate [m^2/day]
- c_a the constituent concentration in the overlying water column [g/m^3]

c_s the constituent concentration in the sediment
[g/m³]

H_s thickness of the sediment top layer [m]

ρ_{por} the porosity of the sediment top layer [-]

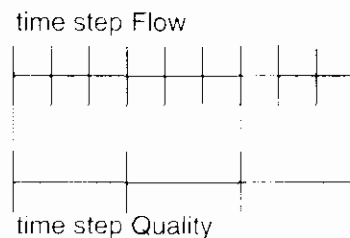
The description of the exchange flux has to be added to the differential equation describing the processes of the constituent. Both the depth of the sediment top layer and the exchange rate should be declared as a parameter.

In principle more complex descriptions can also be used to describe the sediment water interactions. Another example is given in EUBOD 2 (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_i 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:

$$\sum_j M_{ij} H_j = R_i \quad (30)$$

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.

$$\begin{array}{c}
 \begin{matrix} & i & j \\ \begin{matrix} i \\ j \end{matrix} & \begin{pmatrix} * & * \\ * & * \end{pmatrix} \end{matrix} & \bullet & \begin{pmatrix} * \\ * \end{pmatrix} = \begin{pmatrix} * \\ * \end{pmatrix} \\
 \text{M} & & \text{H} = \text{R}
 \end{array}$$

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 or 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:

$$E_{num} = \frac{u}{2} (1 - 2\theta) \mu \Delta t \quad (31)$$

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 therefore 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.
- *Comments* start with */** and end with **/*.
- An *include statement* can be used to include parts of the DUPROL code from other files (syntax: #include "<filename>", for <filename> the name of the file must be substituted)

A model file consists of the parts:

- Declaration section:
In this part the different variables are defined.
- Compound statement for water courses:
This part contains the equations describing the processes in the water courses.
- Compound statement for weirs, general structures and culverts:
The mass transfer of gasses and volatile substances at these structures can be modelled. Although the concept was originally introduced to simulate the enhanced oxygen transfer at weirs, it also can be used to describe the release of volatile substances. This part is optional.
The weirs part starts with the keyword 'weirs'.

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 Auto-simulation Model - HETP (HETP) - DUBLIN
/*
/* Hans Auerhainz & Peter Furrer
/*
/* Applied and Environmental Microbiology
/* Department of Water Contamination
/* Water Quality Management Division
/* City of Dublin
/* City of Dublin
/*
/*
/* September 1990
/*

water A 1 2.000 mg/l ;Water Depth
water PAR1 1 0.000 mg/l ;Photosynthet.Phot.
water PAR2P2 1 0.000 mg/l ;Photosynthet.Phot.
water NH4 1 3.000 mg/l ;Ammonia
water NO3 1 3.000 mg/l ;Nitrate
water NO3P1 1 0.000 mg/l ;Nitrate.Nitrogen
water uk 1 0.000 mg/l ;Urea
water BOD 1 0.000 mg/l ;BOD
water SS 1 3.000 mg/l ;Suspended Solids
parr kp 1 0.000 mg/l ;Monopentant Phosphate
parr kr 1 0.000 mg/l ;Monopentant Nitrogen
parr gwp 1 0.000 mg/l ;Specific growth rate constant
parr q 1 0.000 l/mg ;Biomass yield
..
..
..

xt ssp 1 0.000 g/l ;Suspended Solids
xt t 1 0.000 mg/l ;Temperature
xt rwp 1 0.000 g/l ;Suspended Solids
xt plux 1 0.000 mg/l ;Phosphate release flux ingredient
xt tflux 1 0.000 g/l ;Ammonia release flux ingredient

flow z 1 2.000 m ;Water Depth
flow Q 1 0.000 m3/day ;Flow
flow An 1 19.000 m2 ;Cross sectional Area
flow Warea 1 1 m2 ;Area of the reactor
flow rarea 1 1 ;Reactor depth

{
  fSpars = f1*exp(-f2*x);
  fKp1 = PAR1*P1*exp(-f3*x);
  fKp2 = PAR2*P2;
  fKp3 = fKp1 + fKp2;

  In: MIN(PORTS, fKp3 TO -kp, fNH4*(1-z) - NH4*(1-z)*zn);
  etof = fKp3*P1*exp(-f3*x);
  fN = fNH4*(1-z);
  fN2 = f1*f2*exp(-f3*x) + fKp3*P1*exp(-f3*x) - fN*(1-z)*zn;
  fN3 = fN2*f3;
  Gprod = fN*(1-z)*f1;
  Reap = kr*fN*(1-z)*f1*exp(-f3*x);
  ZFA = fN*(1-z)*f1;
  ..
  ..

  Ptot = PAR1+PAR2*P2+A*f1;
  N2 = fNH4*(1-z)*f1;
  N3 = N2*f3;
}

Weird:
{
  /* f1, f2, f3, f4, f5, f6, f7, f8, f9, f10, f11, f12, f13, f14, f15, f16, f17, f18, f19, f20, f21, f22, f23, f24, f25, f26, f27, f28, f29, f30, f31, f32, f33, f34, f35, f36, f37, f38, f39, f40, f41, f42, f43, f44, f45, f46, f47, f48, f49, f50, f51, f52, f53, f54, f55, f56, f57, f58, f59, f60, f61, f62, f63, f64, f65, f66, f67, f68, f69, f70, f71, f72, f73, f74, f75, f76, f77, f78, f79, f80, f81, f82, f83, f84, f85, f86, f87, f88, f89, f90, f91, f92, f93, f94, f95, f96, f97, f98, f99, f100, f101, f102, f103, f104, f105, f106, f107, f108, f109, f110, f111, f112, f113, f114, f115, f116, f117, f118, f119, f120, f121, f122, f123, f124, f125, f126, f127, f128, f129, f130, f131, f132, f133, f134, f135, f136, f137, f138, f139, f140, f141, f142, f143, f144, f145, f146, f147, f148, f149, f150, f151, f152, f153, f154, f155, f156, f157, f158, f159, f160, f161, f162, f163, f164, f165, f166, f167, f168, f169, f170, f171, f172, f173, f174, f175, f176, f177, f178, f179, f180, f181, f182, f183, f184, 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```

```

}
weirs
/
#include "recreation.inc"
}

```

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)
Fallh	Fall height (m) defined as the distance between the sill level of the structure and the water level down stream of the structure.
He	Thickness of the over flowing water
Width	The width of a structure

The latter three flow variables may only be used in the weirs section of the quality model. In the figure below the meaning of the several

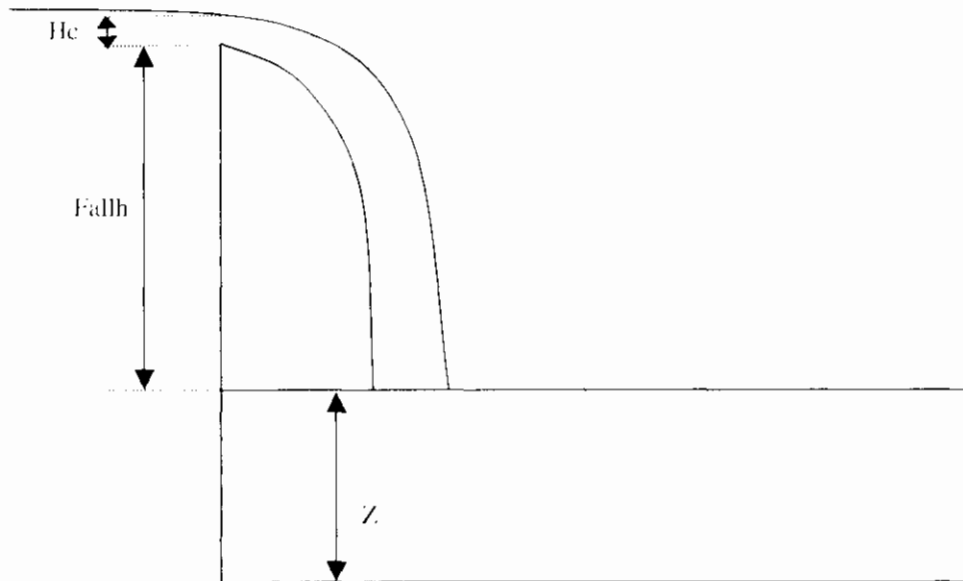


Figure 3.1 Definition of flow variables at structures

<i>water,</i> <i>bottom,</i> <i>xt,</i> <i>parm,</i> <i>flow</i>	identifier	[default]
	Dimension	:
	Description	<return>

Figure 3.2 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 DUFFLOW          */
/* remarks: No physical meaning                               */
/*                                                           */
water  A      [ 2.000]  ug-C/l      ;Algal biomass
water  O2     [19.000]  mg/l       ;Oxygen
water  BOD    [ 5.000]  mg-O2/l    ;BOD
water  SS     [16.000]  mg/l       ;Suspended solids

parm   kp     [ 0.000]  mg-P/l    ;Monod-constant P algal growth
parm   kn     [ 0.000]  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]  °C       ;Temperature
xt     resf   [  0.50]  g/m2.day  ;Resuspension flux

```

3.1.3 Compound statement

3.1.3.1 Processes in sections

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:

$$\frac{\partial C}{\partial t} = k_a (C_s - C) - k_d L \quad \text{should be rearranged like:}$$

$$\frac{\partial C}{\partial t} = -k_a C + k_a C_s - k_d L$$

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.

3.1.3.2 Rearrangement at structures

3.1.3.3 Compound statements

A compound statement consists of statements. Two types of statements are available:

- formula See section 3.1.3.4
- if-statement See section 3.1.3.5

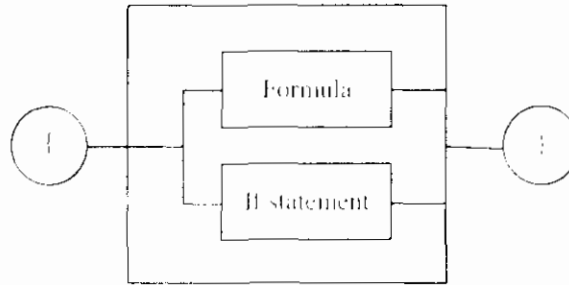


Figure 3.3 Syntax of a compound statement

3.1.3.4 Formula

The general syntax of a formula is shown in

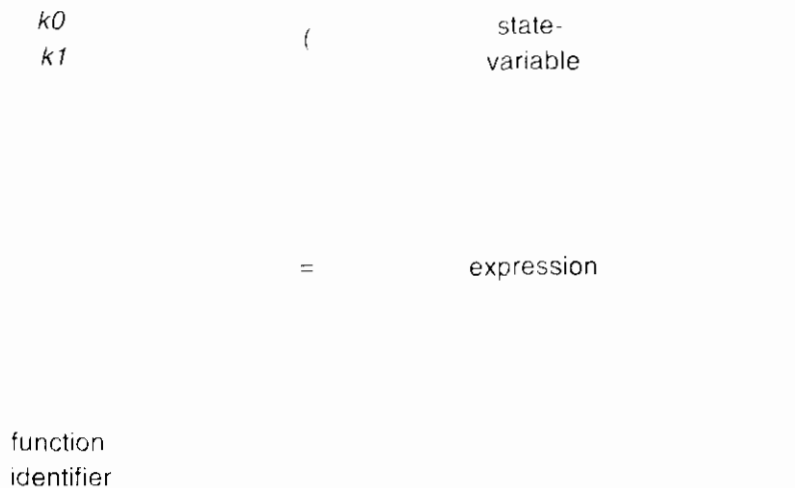


Figure 3.4 Syntax of Formula

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) (e ^x)
+	ln(x)
-	log(x) (¹⁰ log(x))
	abs(x) (x)
	min(x1,x 2,..., xn)
	max (x1, x2,... ,xn)
	int(x) (truncate x to integer value)
	Round(x) (round x to integer value)
	asin(x) (arc sine(x))
	acos(x) (arc cosine(x))
	atan(x) (arctangent(x))
	rnd (random value)

3.1.3.5 If-statement

DUPROL contains a flow-control statement. The syntax of this statement is shown in Figure 3.5.



Figure 3.5 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 ((Pop>=1.0) && (Lap!=0.0))
    {
        Kip=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).

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 discharge to and from the groundwater to the water course has consequences for the water level in 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 MODUFLOW one 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.

MODUFLOW maps 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 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:

- 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 Introduction

A Duflow calculation is divided into three steps. In the first step the Network is converted. In this conversion calculation points are defined and – based on the Cross Sections – the cross sectional profile at the Duflow points are defined. Next the input data of the Network window is written to the so-called Duflow files. These Duflow files contain ASCII text. In this chapter the format of these files are described. Finally the calculation is performed and the results are stored in the results files. Also the format of these results files are described.

5.1.1 File types

There are four groups of file types:

- **General Duflow files**
These files are created and used in every Duflow calculation and contain general information about the calculation and the network.
- **Duflow Flow files**
These files are created and used in Duflow flow calculations and contain water quantity information about the model.
- **Duflow Quality files**
These files are created and used in Duflow quality calculations and contain water quality information about the model.
- **Import and Export files**
These files are used to read or write data of the model

The following file types can be distinguished:

Filename	Extension	Description
General DufLOW files		
Conversion file	*.SID	File containing the conversion of the DMS objects-ID's to DufLOW-ID's
Control Settings File	*.CTR	File that contains the input data entered in "Control data"
Network File	*.NET	The nodes are connected through a network. The Network File contains the network, and its geographical dispersion
DufLOW Flow files		
Initial Conditions Flow File	*.BEG	In this file all initial conditions related to the flow are stored
Boundary Conditions Flow File	*.BND	In this file all boundary conditions related to the flow are stored.
Flow Results File	*.RES	This file contains the results from a flow-calculation
DufLOW Quality files		
Initial Conditions Quality File	*.BEK	In this file all initial conditions related to the quality are stored.
Boundary Conditions Quality File	*.BNK	In this file all boundary conditions related to the quality are stored.
External Variables File	*.EXT	In this file all external variables of the quality model are stored.
Parameters File	*.PRM	In this file all parameters of the quality model are stored.
Quality Results File	*.REK	This file contains the results for the Quality Variables from a quality calculation
Import/Export files		
Monitoring file	*.MON	This file contains information about the the water quantity situation on every timestep during the calculation
Time Series file	*.TSS	This files contains one or more time series of the boundary conditions, including the related object-ID's.
Time Series file (single time series)	*.TSE	This files contains one time series.

5.1.2 File format version

By selecting the option 'Generate version 2.05 files' in the Scenario Properties dialog the user can choose to write the DufLOW files to the old format. This option makes it possible to compare the results in DMS with the results from DufLOW for DOS 2.0x. Note that the 2.05 format is not millennium proof. In new DMS-projects default the 3.0 file format is used. In this chapter both formats – if applicable – are described.

The first line in each file starts with: +, it gives an identification of the file format. Files in the 3.0 file format start with the text: '+VERSION=3.0'.

The lines 2 till 4 gives information about the related project as comment.

File format version 2.05

In general the positions in the 2.05 format 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.

File format version 3.0

The 3.0 file format is explained with a notation at the beginning of the lines in the example files. The following notations are used:

Notation	Fortran format
a200	200 characters
4x	4 blank spaces
i10	integer number, 10 positions
3g7.0	3 real numbers, 7 positions
card(6:55)	a card is a character string, in this case the sting deals with position 6 - 55
g16.8	real number, 16 positions from which 8 positions are behind the decimal sign

General Duflow files

5.2 SID – Standard Exchange Format ID

In DMS all network objects have can be indentified by an object ID. An other term for the object ID is 'Standard Exchange Format ID' (Dutch 'Standaard Uitwisselingsformaat ID' – SUF ID). Before a calculation can be made, the DMS-network is converted, calculation points are added etc. During this conversion Duflow assigns other numbers to the converted DMS-objects. These so called 'Duflow numbers' are written in the Duflow files. The conversion of Object-ID to Duflow number is written in this file.

The SID-file also contains the coördinates of the DMS-objects.

(x4,a4,a8,i16,i16,i8,i8)	NOD ^a	NOD1 ^b	4119	0	6
(x4,a4,a8,i16,i16,i8,i8)	NOD	NOD6	4119	0	6
(x4,a4,a8,i16,i16,i8,i8)	NOD	NOD11	11999	0	12
(x4,a4,a8,i16,i16,i8,i8)	NOD	NOD12	5267	0	7
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00000	823	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00001	1667	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00002	2471	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00003	3295	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00004	6213	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00005	7165	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00006	8156	0	-1
(x4,a4,a8,i16,i16,i8,i8)	CLC	CLC00007	9553	0	-1
(x4,a4,a8,i16,i16,i8,i8)	WEI	WEI1	4818	0	6

The following list gives explanation about the items in the file.

- a "Object type", possible values are
- NOD Node
 - SCH Schematization Point
 - DIS Discharge point
 - ARE Area

- a "Start of computation" (date) in yymmdd (2.05) or yyyyymmdd (3.0)
- b "Start of computation" (time) in hhmm
- c "End of computation" (date) in yymmdd (2.05) or yyyyymmdd (3.0)
- d "End of computation" (time) in hhmm
- e "Start of output" (date) in yymmdd (2.05) or yyyyymmdd (3.0)
- f "Start of output" (time) in hhmm
- g "Time step flow" in minutes
- h "Time step output" in minutes
- i "Resistance formula", possible values are;
 - 0=Manning
 - 1=De Chezy.
- j I - "theta", hydraulic part of the model.
- k "Calc. of advection term", possible values are;
 - 0=Total
 - 1=Neglected
 - 0=Damped.
- l "Extra iteration", possible values are;
 - 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" ", possible values are;
 - 0=No
 - 1=Yes
- r "Create intermediate flow file" ", possible values are;
 - 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;

(4x,6g7.0)
(4x,6g7.0)

EJBY	1	2	3	4	5	6
ZJBY	7	8	9	0	1	2

- s "Locations for output", sectionnumber(s) or structure number(s) 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=norq
- 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

5.4 NET – Network

The Network File contains data from the Network Window including the nodes, sections, crosssections and all available structures.

- Pump;
- Gap growth.

5.4.1 Weir

Below a weir example is shown.

```
STRU 1d 2c 3f 4e 1.00f 1.00g 999.0g
MU 1.000i 1.000j
```

The following list gives explanation about the items in an overflow.

- a “Duflow 'section/structure' number”
- b “Duflow 'section/structure' number”
- c “Duflow 'node' number” of the begin node of the weir
- d “Duflow 'node' number” of the 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

5.4.2 Underflow – General Structure

The next example deals with a general structure.

```
STRU 2a 2b 4c 5d 1.75e 2.25f -1.25h
MU 1.0E-8i 0.170j 0.360k 0.800l
```

The following list gives explanation about the items in a general structure.

- a “Duflow 'section/structure' number”
- b “Duflow 'section/structure' number”
- c “Duflow 'node' number” of the begin node of the general structure
- d “Duflow 'node' number” of the 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

5.4.3 Culvert

The next example deals with a rectangular culvert.

```
STRU 1a 2b 3c 7d 100e 3.00f 2.00g 1.00h
MU 1.00i 0.00j 0.00k 0.00l
```

The following list gives explanation about the items in a culvert.

- * Tube form of the culvert;

MU = Rectangular
 E.L.L = Elliptic or Round

- a "Duflow 'section/structure' number"
- b "Duflow 'section/structure' number"
- c "Duflow 'node' number" of the begin node of culvert
- d "Duflow 'node' number" of the end node of the culvert
- e "Length" of the culvert
- f "Sill level", culvert
- g "Width", culvert
- h "Gate level" i.e. "Sill level"+"Height", culvert
- 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
- m "Chezy coefficient", culvert

The next example deals with an elliptic culvert.

```

CULVT  33  42  61  6.000  1.000  1.000  1.000  1.000  1.000
E.L.L  1.000  1.000  1.000  1.000  1.000  1.000  1.000
  
```

The following list gives explanation about the items in an culvert.

- * Tube form of the culvert:
 - MU = Rectangular
 - E.L.L = Elliptic, Egg or Round
- a "Duflow 'section/structure' number"
- b "Duflow 'section/structure' number"
- c "Duflow 'node' number" of the begin node of the culvert
- d "Duflow 'node' number" of the 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" (positive direction)
- m "Chezy coefficient", culvert

5.4.4 Siphon

The next example deals with a siphon.

```

SIPHON  43  42  61  6.000  1.000  1.000  1.000  1.000
E.L.L  1.000  1.000  1.000  1.000  1.000  1.000  1.000
  
```

The following list gives explanation about the items in a siphon.

- a "Duflow 'section/structure' number"
- b "Duflow 'section/structure' number"
- c "Duflow 'node' number" of the begin node of the siphon
- d "Duflow 'node' number" of the end node of the siphon
- e "Length" of the siphon
- f "Diameter", of the siphon
- g "Chezy coefficient" of the siphon

- 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

5.4.5 Pump

The next example deals with a pump.

```

STRU 5a 6b 17c 16d
PUMP 6.6699e 6.99f 6.99g 16d

```

The following list gives explanation about the items in a pump.

- a "Duflow 'section/structure' number"
- b "Duflow 'section/structure' number"
- c "Duflow 'node' number" of the begin node of the pump
- d "Duflow 'node' number" of the end node of the pump
- e "Capacity", of the pump
- f "Start level"
- g "Stop level"

5.4.6 Gap growth

The next example deals with a gap growth.

```

STRU 6a 6b 17c 18d 7e -1.20f -5.00g 999.0h
BRES 1.000i 1.000j 349267k 6l 6.5m 10.0n 5400o 5400p

```

The following list gives explanation about the items in a gap growth.

- a "Duflow 'section/structure' number" (no meaning)
- b "Duflow 'section/structure' number"
- c "Duflow 'node' number" of the begin node of the gap growth structure
- d "Duflow 'node' number" of the end node of the 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


```
(a200)
(a200)
(a200)
(a200)
(a4,2q7.0,116,3q7.0)
(a4,6q16.8)
(a4,2q7.0,116,3q7.0)
(a4,6q16.8)
```

```
+VERSION 3.0
* DDFLOW data file :C:\Witrouflow\Projects\Estron1\Scenario1.BND
* Flow Bound. cond./etc. ctrl .program version: 3.00
#
#-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
H-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
Q-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
R-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
W-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
T-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
```

The following list gives explanation about the items in the file.

- a "Type" of boundary:
 - H = "Level"
 - Q = "Q add."
 - R = "Rain"(Precipitation), not used in DMS
 - W = "Wind velocity"
 - T = "Wind direction"
- b "Duflow 'node' number(s)" (2.05 format: positions 60 till 83)
- c "Type of function" = "Constant"
- d Entered value for "Constant"
- e Condition number (no meaning in DMS)

5.6.2 Equidistant time series

Below an example is given, dealing with a "Level" boundary type with "Equidistant time series" specification.

Version 2.05 file format

```
#-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
H-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
Q-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
R-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
W-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
T-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
```

Version 3.0 file format

```
(a4,2q7.0,116,3q7.0)
(a4,6q16.8)
(a4,6q16.8)
```

```
#-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
H-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
Q-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
R-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
W-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
T-----a-----b-----c-----d-----e-----f-----g-----h-----i-----j-----k-----l-----m-----
```

The following list gives explanation about the items in the file.

- a "Type" of boundary:
 - H = "Level"
 - Q = "Q add."
 - R = "Rain"(Precipitation), not used in DMS
 - W = "Wind velocity"
 - T = "Wind direction"
- b "Time step" in minutes
- c "Start data", in yymmdd (2.05) or yyymmdd (3.0)
- d "Start time", in hhmm
- e Condition number (no meaning in DMS)
- f "Duflow 'node' number(s)" (2.05 format: positions 60 till 83)
- g 1st value of "Time series"
- h 2nd value of "Time series"
- i 3rd value of "Time series"
- j 4th value of "Time series"
- k 5th value of "Time series"
- l 6th value of "Time series"
- m 7th value of "Time series"


```
(a4,2q7.0,110,3q7.0)
(a4,2q7.0,i10,3q7.0)
(a4,6q16.8)
(a4,q16.8,3q7.0)
```

```
QH a 720c 13364101c 0000d 1e 1f
HT c 0.33d 0.33e 0.37f 0.36g 0.35h
Q1 i 1.01000000j 1.02000000k 1.04000000l 1.05000000m
```

The following list gives explanation about the items in the file.

- a "Type" of boundary:
 - H = "Level"
 - Q = "Q add."
 - R = "Rain"(Precipitation), not used in DMS
 - W = "Wind velocity"
 - T = "Wind direction"
- b Period in minutes
- c "Start date", in yymmdd (2.05) or yyyyymmdd (3.0)
- d "Start time", in hhmm
- e Condition number (no meaning in DMS)
- f "Duflow 'node' number(s)" (2.05 format: positions 60 till 83)
- g "Type of function" = "Constant"
- h "Mean value"(y₀ in Fourier series)
- i Entered value for "Amplitude" of kth component
- j Entered value for "Phase" of kth component

5.6.5 QH relation

Below an example is given, dealing with a "QH-relation" boundary type.

Version 2.05 file format

```
QH a 2c
HT c 0.33d 0.33e 0.37f 0.36g 0.35h
Q1 i 1.01000000j 1.02000000k 1.04000000l 1.05000000m
```

Version 3.0 file format

```
(a4,2q7.0,110,3q7.0)
(a4,6q16.8)
(a4,6q16.8)
```

```
QH a 2b
HT c 0.33000000d 0.33000000e 0.37000000f 0.36...gh
Q1 i 1.01000000j 1.02000000k 1.03000000l 1.04...
```

The following list gives explanation about the items in the file.

- a Indication "QH-relation" boundary type
- b "Duflow 'node' number(s)" (2.05 format: positions 60 till 83)
- 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

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 free surface positive";
 - TMV2 = "Mu free surface negative";
 - TMO1 = "Mu submerged positive";
 - TMO2 = "Mu submerged negative".
- b "Duflow 'structure' number"
- c "Type of trigger condition":
 - TIME = "Time";
 - H2H1 = " $H2 < H1 + \delta H$ ";
 - H1H2 = " $H1 > H2 + \delta H$ ";
 - HPP = "Hnode > Htrig";
 - HPM = "Hnode < Htrig".
- d Date of "Time", in yymmdd (2.05) or yyyyymmdd (3.0).
- 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 - Results Flow

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 2.05 file format

WINDOW FILE (2.1.1)

```

C:\Window\Project\1\window1.DDF
C:\Window\Project\2\window2.DDF
C:\Window\Project\3\window3.DDF
C:\Window\Project\4\window4.DDF
C:\Window\Project\5\window5.DDF
C:\Window\Project\6\window6.DDF
C:\Window\Project\7\window7.DDF
C:\Window\Project\8\window8.DDF
C:\Window\Project\9\window9.DDF
C:\Window\Project\10\window10.DDF
C:\Window\Project\11\window11.DDF
C:\Window\Project\12\window12.DDF

```

WINDOW

NO.	DATE	TIME	LOCATION	DEPTH	VELOCITY	ACCELERATION	PERIOD	AMPLITUDE
1	288	1	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
2	288	2	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
3	288	3	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
4	288	4	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
END/DATA								
1	1	1	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
2	2	2	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
3	3	3	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
4	4	4	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
5	5	5	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
6	6	6	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
7	7	7	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
8	8	8	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
9	9	9	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
10	10	10	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
11	11	11	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
12	12	12	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
288	1	1	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
288	2	2	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
288	3	3	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01
288	4	4	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01	1.111E+01

Version 3.0 file format

VERSION 3.0

C:\Windflow Projects Scenario.GTP
 C:\Windflow Projects Scenario.NET
 C:\Windflow Projects Scenario.NOD
 C:\Windflow Projects Scenario.BND
 C:\Windflow Projects Scenario.BEG
 C:\Windflow Projects Scenario.PED
 C:\Windflow Projects Scenario.BNY
 C:\Windflow Projects Scenario.BEX
 C:\Windflow Projects Scenario.MGR
 C:\Windflow Projects Scenario.FXT
 C:\Windflow Projects Scenario.PPM
 C:\Windflow Projects Scenario.PRY

ENDNAM

	0	288 ^a	0	0	4 ^b	0	0	0	0	0
	0	4 ^c	0	0	0	0	0	0	0	0
19910701		6 ^d						600 ^e		
LEVEL		6.00000000E+00 ^{w1}			6.95893669E+00 ^{w2}					
DISCHARGE		-4.76237158E-06 ^{x1}			3.19112968E+00 ^{x2}					
VELOCITY		0.00000000E+00 ^{y1}			1.26657555E+00 ^{y2}					
DEPTH		3.00000000E+00 ^{z1}			3.35893669E+00 ^{z2}					

ENDIP

	1	1	1	1	2	1000 ^f	-2.0000E+00 ^h	-2.0000E+00 ^g
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 ^f	1 ^g	0.00000000E+00 ⁱ	0.00000000E+00 ^j	1.00000000E+00 ^k	1.00000000E+00 ^l	0.00000000E+00 ^m	0.00000000E+00 ⁿ
0	2	0.00000000E+00	0.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	0.00000000E+00	0.00000000E+00
0	3	0.00000000E+00	0.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	0.00000000E+00	0.00000000E+00
0	4	0.00000000E+00	0.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	0.00000000E+00	0.00000000E+00
3	1	4.23330000E-03	3.42745000E-03	1.00000000E+00	1.00000000E+00	9.89630000E-01	9.89630000E-01	4.96460000E-02
3	2	3.42745000E-03	2.65630000E-03	1.00000000E+00	1.00000000E+00	9.89630000E-01	9.89630000E-01	4.96460000E-02
3	3	2.65630000E-03	1.45020000E-03	1.00000000E+00	1.00000000E+00	9.89630000E-01	9.89630000E-01	4.96460000E-02
3	4	1.45020000E-03	0.00000000E+00	1.00000000E+00	1.00000000E+00	9.89630000E-01	9.89630000E-01	4.96460000E-02
:	:	:	:	:	:	:	:	:
288	1	2.79430000E-03	2.03710000E-03	1.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	4.99390000E-02
288	2	2.03710000E-03	1.39880000E-03	1.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	4.99560000E-02
288	3	1.39880000E-03	6.99710000E-04	1.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	4.99740000E-02
288	4	6.99710000E-04	0.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	1.00000000E+00	4.99910000E-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 (2.05) or yyyyymmdd (3.0)
- g "Start of computation" (time) in hhmm
- h Line number
- i "Sectiontype";
 SECT = "Section"
 STRU = "Structure"
- j "Duflow 'section/structure' number" from the NET-file
- k "Duflow 'node' number" of the begin node of the section
- l "Duflow 'node' number" of the end node of the section
- m "Lenght" of the section
- n "Bottom level", begin
- o "Bottom level", end
- p Flow time step number
- q "Duflow 'section/structure number" from the NET-file
- r Water level at beginning of section
- s Water level at end of section
- t Discharge at beginning of section

5.9 BNK – Boundary Conditions Quality

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 (Scenario.BNK), of the appendix A (EUTROFI).

Version 2.05 file format

```
*
* DUFLOW data file (C:\Windflow Projects\Bnkof1\Scenario.BNK)
* Quality Boundary conditions      program version: 2.05
*
*
*   a                1b         a         c         1d
*   ----e 1.900000000f
*   C
*   P          9.300000
*   C
*   P          3.600000
*   C
*   P          0.800000
*   C
*   P          10.00000
*   C
*   P          9.640000
*   C
*   P          0.110000
*   C
*   P          5.000000
*   C
*   P          5.000000
```

Version 3.0 file format

```
(a200)
(a200)
(a200)
(a200)
(a4,2g7.0,110,3g7.0)
(a4,6g10.8)
```

```
*VERSION 3.0
* DUFLOW data file (C:\Windflow Projects\Eutrofi\Scenario.BNK)
* Quality Boundary conditions      program version: 3.00
*
*
*   a                1b         a         c         1d
*   ----e 1.900000000f
*   C
*   P          9.300000000
*   C
*   P          3.600000000
*   C
*   P          0.800000000
*   C
*   P          10.000000000
*   C
*   P          9.640000000
*   C
*   P          0.110000000
*   C
*   P          5.000000000
*   C
*   P          5.000000000
```

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 "Duflow 'node' number"
- e "Type of function" = "Constant"
- f Value for the "Variable"

f "Time step", in minutes
 g "Start data", in yymmdd (2.05) or yyyyymmdd (3.0)
 h "Start time", in hhmm
 i First value of "Timeseries"
 j Last value of "Timeseries"

5.11 PRM – Parameter

In the Parameter File all parameters defined in the process description file are stored.

Below is shown the parameter file (Scenario.PRM), of the appendix A (EUTROFI).

Version 2.05 file format

```
+
* DUFLOW data file :C:\Winduflow\Projects\Eutrofi Scenario.PRM
* Quality Parameters      program version: 2.05
+
achioa      30.000b
anc          0.100
apc          2.670
apc          0.010
eb          2.000
ealg        0.017
:           :
:           :
:           :
vsc          0.500
vsc          1.000
```

Version 3.0 file format

```
(a200) +VERSION 3.0
(a200) * DUFLOW data file:C:\Winduflow\Projects\Eutrofi Scenario.PRM
(a200) * Quality Parameters      program version: 3.00
(a200) *
(a50,2x,q16.8) achio-----a----- 30.00000000b
anc          0.10000000
apc          2.67000000
apc          0.01000000
eb          2.00000000
ealg        0.01700000
:           :
:           :
:           :
vsc          0.50000000
vsc          1.00000000
```

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 – Results Quality

In the Quality Data - Result File all the quality results are stored.

Version 2.05 file format

WINDFLOW.DAT: 1.000

C:\Windflow\Project1\1000\10001
 C:\Windflow\Project1\1000\10002
 C:\Windflow\Project1\1000\10003
 C:\Windflow\Project1\1000\10004
 C:\Windflow\Project1\1000\10005
 C:\Windflow\Project1\1000\10006
 C:\Windflow\Project1\1000\10007
 C:\Windflow\Project1\1000\10008
 C:\Windflow\Project1\1000\10009
 C:\Windflow\Project1\1000\10010
 C:\Windflow\Project1\1000\10011
 C:\Windflow\Project1\1000\10012

ALLWIND

1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1

ALLWIND

1	2	3	4	5	6	7	8	9	10	11	12
1	0.001	1	1	1	1	1	1	1	1	1	1
2	0.001	2	2	2	2	2	2	2	2	2	2
3	0.001	3	3	3	3	3	3	3	3	3	3
4	0.001	4	4	4	4	4	4	4	4	4	4

ALLWIND

1	2	3	4	5	6	7	8	9	10	11	12
1	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
2	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
3	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
4	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
5	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
6	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
7	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
8	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
9	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
10	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
11	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
12	1	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
13	4	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
14	4	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
15	4	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00
16	4	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00	1.000000E+00

Version 3.0 file format

-VERSION 3.0

C:\Windflow\Projects\Scenario.COR
 C:\Windflow\Projects\Scenario.HRI
 C:\Windflow\Projects\Scenario.HSO
 C:\Windflow\Projects\Scenario.HNB
 C:\Windflow\Projects\Scenario.HRS
 C:\Windflow\Projects\Scenario.HRD
 C:\Windflow\Projects\Scenario.HNF
 C:\Windflow\Projects\Scenario.HRP
 C:\Windflow\Projects\Scenario.HRF
 C:\Windflow\Projects\Scenario.HRG
 C:\Windflow\Projects\Scenario.HRI
 C:\Windflow\Projects\Scenario.HRM
 C:\Windflow\Projects\Scenario.HRX

```

ENNDNAM
  2a 3b 0 0 4c 5c 1d 1800e 0 0
  12f 6f 0 0 0 0 0 1 0 0
19910701g 6h
ENDIPC
ENDIRG
  1 a
  2 0000
  3 02
  :
  :
ENDVAB
  1i SECTj 1- 1k 1- 2l 1000m -2.0000E+00n -2.0000E+00o
  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
  2q 1r 2.00000000E+00s 2.00000000E+00t 2.00000000E+00u 2.00000000E+00v 0.00000000E+00w
  0 : 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
  0 : 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01
  0 : 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
  0 : 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01
  0 : 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01
  0 : 0.00000000E+02 0.00000000E+02 0.00000000E+02 0.00000000E+02 0.00000000E+02
  0 : 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01 0.00000000E+01
  : : : : :
  : : : : :
  36 4 0.00000000E+01 0.00000000E+01 0.00000000E+00 0.00000000E+00 0.00000000E+00
  36 4 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
  36 4 0.00000000E+01 0.00000000E+01 0.00000000E+00 0.00000000E+00 0.00000000E+00
  36 4 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+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 (2.05) or yyyyymmdd (3.0)
- h "Start of computation" (time) in hhmm
- i Line number
- j "Sectiontype";
 SECT = "Section"
 STRU = "Structure"
- k "Duflow 'section/structure' number" from the NET-file
- l "Duflow 'node' number" of the begin node of the section
- m "Duflow 'node' number" of the end node of the section
- n "Lenght" of the section
- o "Bottom level", begin.
- p "Bottom level", end.
- q Quality time step number.
- r Duflow '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.
- x1 Minimum Concentration, i.e. lowest value columns 's' and 't'
- x2 Maximum Concentration, i.e. highest value columns 's' and 't'
- y1 Minimum Load, i.e. lowest value columns 'u' and 'v'
- y2 Maximum Load, i.e. highest value columns 'u' and 'v'

5.13 MON – Monitoring file

The results of a flow calculation can also be to a monitoring file. The monitoring file contains information about calculated values like streaming profile, resistance etc. on each time step.

To write data to the monitoring file, the option 'Add to monitoring file' – which is a property of a section (Objects Properties dialog) - need to be checked.

```

TimeStep      68  5/11/02  11:11:13
SECTION      H1      H2      Q1      Q2      V      A1      A2      B1      B2      WITH R*Q**2 P*Q**2
2  6.988d  7.978e  6.23f  6.29g  0.26h  24.84i  24.28j  21.22k  21.17l  11.07m  11.07n  11.07o  11.07p
3  7.978  7.798  6.23  6.25  0.28  23.28  21.59  28.13  24.17  11.07  11.07  11.07  11.07
SECTION      H1      H2      Q1      Q2      V      A      SILL  WITH  GATE  NO FORMULA
4  7.978d  6.148e  6.23f  6.13g  0.2h  6.30i  2.17  222.13j  11.07k
SECTION      H1      H2      Q1      Q2      V      A1      A2      B1      B2      WITH R*Q**2 P*Q**2
5  6.148  6.556  6.23  6.36  0.54  11.92  11.92  11.92  11.92  11.92  11.92  11.92  11.92
TimeStep      69  5/11/02  11:56:15
SECTION      H1      H2      Q1      Q2      V      A1      A2      B1      B2      WITH R*Q**2 P*Q**2
2  8.589  7.978  6.56  6.98  0.75  24.27  24.03  21.14  18.13  11.07  11.07  11.07  11.07
3  7.978  7.798  6.22  6.25  0.38  23.56  21.18  28.13  14.13  11.07  11.07  11.07  11.07
SECTION      H1      H2      Q1      Q2      V      A      SILL  WITH  GATE  NO FORMULA
4  7.978  6.148  6.23  6.13  0.2  6.33  2.17  222.13  11.07
SECTION      H1      H2      Q1      Q2      V      A1      A2      B1      B2      WITH R*Q**2 P*Q**2
5  6.148  6.556  6.23  6.36  0.74  11.92  11.92  11.92  11.92  11.92  11.92  11.92  11.92

```

The following list gives an explanation about the items in the file.

- a Flow time step "number"
- b "Date" and "time" of flow time step
- c "Duflow number" of the section
- d "Water level" at beginning of section
- e "Water level" at end of section
- f "Discharge" at beginning of section
- g "Discharge" at end of section
- h "Velocity" averaged over the section
- i "Flow area" at the begin of the section
- j "Flow area" at the end of the section
- k "Storage area" at the begin of the section
- l "Storage area" at the end of the section
- m "Storage width" averaged over the section
- n Value of the formula "R*Q²", with:
R = Hydraulic Radius averaged over the section
C = Resistance
- o "Duflow number" of the structure
- p "Water level" at beginning of structure
- q "Water level" at end of structure
- r "Discharge" through the structure
- s "Velocity" in the structure
- t "Flow area" in the structure
- u "Sill level"
- v "Width"

- w "Gate level", in case off a weir is set to 999.0
- x "Mu"
- y "Flow condition number" of the flow condition in the structure, more information about the flow condition number is described in paragraph 2.2.4.2

5.14 TSS – Time Series File

With the DMS command 'Export Time Series' the user can write all Boundary Conditions for Level, Discharge, Concentration and Load to an external ASCII-file. DMS will create a so-called Time Series file (*.TSS). A file in this format can also be imported in DMS with the command 'Import Time Series'. By means of this file the user can import several time series into the Duflow model.

When in the Modify Time Series dialog only one time series is exported to an ASCII-file, the data are stored in a *.TSF file. The format of this file is identical to the format of the *.TSS file.

Numerical values in this file are seperated by tab-characters.

Lines beginning with character '#' are ignored.

- c the time series consists of a constant value. (time and date are not used)
 - f the time series is defined by means of a fourier series
 - e the time series is a equidistant time series
 - n the time series is a non-equidistant time series
- In the above example the different possibilities are given.

- g Date defined by: yyyy/mm/dd
- h Time defined by: hh:mm:ss
- i Constant value.
- j Period in minutes.
- k Mean value (y_0 in Fourier series)
- l Phase of k^{th} component
- m Amplitude of k^{th} component
- n Time step in minutes
- o n^{th} Value of time series

5.15 TSF – Time Serie File (single time series)

In the Modify Time Series dialog only one time series can be exported to an ASCII-file with the Export-button. The time series is written in a file with the extension *.TSF. The format of this file is identical to the format of the *.TSS file.

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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 extent. 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 (g/l)

These variables are often monitored, so a direct comparison between measurements and simulated results is possible for these constituents.

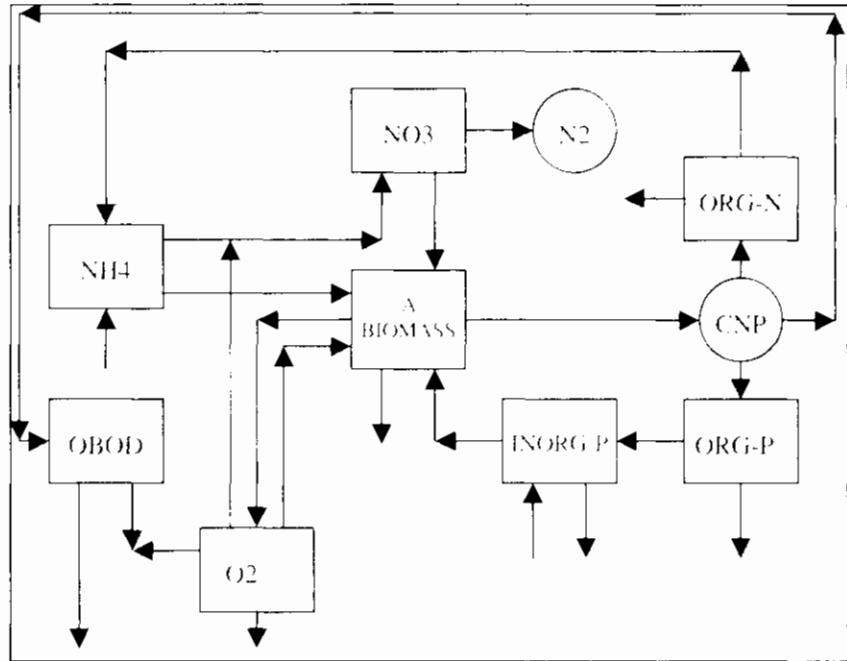


Figure A-1 EUTROFIT State variable interactions

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

$$\frac{dA}{dt} = [\mu_{max} F_l F_N F_T] A - [k_{de} \theta_m^{T-20} + k_{die}] A \quad (A-1)$$

1) Algal growth is considered to be limited by nutrients, light and temperature. Nutrient limitation is described as:

$$F_N = \min \left[\frac{P_{ortho}}{P_{ortho} + K_N} \frac{(NH_4 + NO_3)}{(NH_4 + NO_3) + K_N} \right] \quad (A-2)$$

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

$$\text{equation: } F_l = \frac{e}{\epsilon_{tot} \tau} \left[\exp\left(-\frac{I_0}{I} \exp(-\epsilon_{tot} \tau)\right) - \exp\left(-\frac{I_0}{I}\right) \right]$$

$$(A-3) \text{ in which: } \epsilon_{tot} = \epsilon_{chl} + \epsilon_{chl} \cdot Chl - a + \epsilon_{SS} \cdot SS$$

(A-4) Temperature dependency of the algal growth rate is given

$$\text{by: } F_T = \theta_{gt}^{T-20} \quad (A-5)$$

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

$$\frac{dP_{org}}{dt} = -k_{min} \theta_{min}^{(T-20)} P_{org} - \frac{v_{SS}}{z} (1 - f_{dporg}) P_{org} + f_{porg} [k_{res} \theta_{ra}^{(T-20)} + k_{die}] a_{pc} A \quad (A-6)$$

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

$$\frac{dP_{inorg}}{dt} = -\frac{v_{SS}}{z} (1 - f_{dpano}) P_{inorg} + k_{min} \theta_{min}^{(T-20)} P_{org} - \mu_{max} F_T F_N F_I a_{pi} A + (1 - f_{porg}) [k_{res} \theta_{ra}^{(T-20)} + K_{die}] a_{pc} A + \frac{P_{flux}}{z} \quad (A-7)$$

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:

$$f_{dpano} = \frac{1}{1 + K_{pip} SS} \quad (A-8)$$

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

$$\frac{dN_{org}}{dt} = -k_{min} \theta_{min}^{(T-20)} N_{org} - \frac{v_{SS}}{z} (1 - f_{dnorg}) N_{org} + f_{norg} [k_{res} \theta_{ra}^{(T-20)} + k_{die}] a_{nc} A \quad (A-9)$$

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

$$\frac{dNH_4}{dt} = -k_{nit} \theta_{nit}^{(T-20)} \frac{O_2}{O_2 + K_{NO}} NH_4 + k_{den} \theta_{den}^{(T-20)} N_{org} - \mu_{max} F_T F_N F_I a_m P_{NH_4} A + (1 - f_{nox}) [k_{re} \theta_{re}^{(T-20)} + k_{da}] a_w A + \frac{N_{boc}}{z} \quad (A-10)$$

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:

$$P_{NH_4} = NH_4 \frac{NO_3}{(K_{mN} + NH_4)(K_{mN} + NO_3)} + NH_4 \frac{K_{mN}}{(NH_4 + NO_3) + (K_{mN} + NO_3)} \quad (A-11)$$

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

$$\frac{dNO_3}{dt} = -k_{den} \theta_{den}^{(T-20)} \frac{K_{dNO}}{K_{dNO} + O_2} NO_3 + k_{nit} \theta_{nit}^{(T-20)} \frac{O_2}{O_2 + K_{NO}} NH_4 - \mu_{max} F_T F_N F_I a_m (1 - P_{NH_4}) A \quad (A-12)$$

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

$$\frac{dBOD}{dt} = -k_{BOD} \theta_{BOD}^{(T-20)} \frac{O_2}{O_2 + K_{BODO}} BOD - \frac{v_{BOD}}{z} (1 - f_{dBOD}) BOD + k_{die} a_w A - \frac{5}{4} \frac{32}{14} k_{den} \theta_{den}^{(T-20)} \frac{K_{dNO}}{K_{dNO} + O_2} X_{com} \quad (A-13)$$

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 BOD₅ from bod₅. The bod₅, which is produced by die off of the algae is converted to BOD₅. Also the bod used as a carbon source during denitrification is corrected this way.

$$X_{com} = 1 - \exp(-5k_{BOD}^{(T-20)}) \quad (A-14)$$

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

$$\frac{dO_2}{dt} = k_{re} \theta_{re}^{(T-20)} (c_s - O_2) - k_{BOD} \theta_{BOD}^{(T-20)} \frac{O_2}{O_2 + K_{BODO}} \frac{BOD}{X_{com}} - \frac{64}{14} k_{nit} \theta_{nit}^{(T-20)} \frac{O_2}{O_2 + K_{NO}} NH_4 - \frac{32}{12} k_{re} \theta_{re}^{(T-20)} A - \frac{SOD}{z}$$

$$+\mu_{\max} F_T F_N F_I A \left(\frac{32}{12} + \frac{48}{14} a_w (1 - P_{NH_4}) NO_3 \right) \quad (A-15)$$

The mass transfer coefficient for oxygen is given by the following empirical equation:

$$k_{mas} = 3.94u^{0.5}z^{-1.5} \quad (A-16)$$

or if $k_{mas} < k_{rmin}$:

$$k_{mas} = k_{rmin} \quad (A-17)$$

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 k_{re} is given by:

$$k_{re} = \frac{k_{max}}{z} \quad (A-18)$$

The oxygen saturation concentration is also calculated, using an empirical equation:

$$C_s = 14.5519 - 0.373484T + 0.00501607T^2 \quad (A-19)$$

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. *sed* 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

$$\frac{dSS}{dt} = -\frac{v_{SS}}{z} SS + \frac{\Phi_{res}}{z} \quad (A-20)$$

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.

$$P_{orto} = P_{anorg} f_{dpmto} \quad (A-21)$$

$$P_{tot} = P_{org} + P_{anorg} + Aa_{pc} \quad (A-22)$$

$$N_{kj} = N_{org} + NH_4 + Aa_{nc} \quad (A-23)$$

$$N_{tot} = N_{kj} + NO_3 \quad (A-24)$$

$$Chl - a = a_{chl} A \quad (A-25)$$

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	$\mu\text{g Chl-a/mg C}$	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	$\text{mg O}_2/\text{mg C}$	2.67	
a_p	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	$\mu\text{g Chl-a/l.m}$	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_{dporp}	Fraction dissolved organic phosphorus	-	0	
f_{norz}	Fraction algal nitrogen released as NORG	-	1	
f_{porp}	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
$K_{BOD(t)}$	Monod constant oxidation BOD	$\text{mg O}_2/\text{l}$	2.0	
k_{den}	Denitrification rate constant	1/d	0.1	0.0-0.1
K_{dNO}	Monod constant denitrification	$\text{mg O}_2/\text{l}$	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	$\text{mg O}_2/\text{l}$	2.0	
K_P	Monod constant phosphorus	mg P/l	0.005	0.001-0.05
K_{pp}	Partition constant phosphorus	l/mg SS	0.010	
k_{re}	Respiration rate constant	1/d	0.1	0.05-0.2
k_{rmin}	Minimum oxygen transfer coefficient	m/d	0.1	
k_{dic}	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_{zn}	Temperature coefficient algal growth	-	1.047	
θ_{min}	Temperature coefficient mineralisation	-	1.047	
θ_{nit}	Temperature coefficient nitrification	-	1.080	
θ_{re}	Temperature coefficient respiration	-	1.047	

θ_{rea}	Temperature coefficient reaceration	-	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 RIBUT1.EXE.

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
Φ_{res}	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 eutrofi suspended solids are modelled in 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:

$$\frac{dSS_w}{dt} = \frac{v}{Z} - \frac{F_{res}}{Z} \quad (B-1)$$

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:

$$SS_B = \rho * (1 - POR) * 1000 \quad (B-2)$$

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:

$$v_s = \frac{F_{sed}}{\rho * (1 - POR) * 1000} \quad (B-3)$$

$$v_r = \frac{F_{res}}{\rho * (1 - POR) * 1000} \quad (B-4)$$

In which the sedimentation flux F_{sed} is given by:

$$F_{sed} = v_s * SS_w \quad (B-5)$$

The net displacement of the interface is given by:

$$v_{net} = v_s - v_r \quad (B-6)$$

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_{net} .

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.

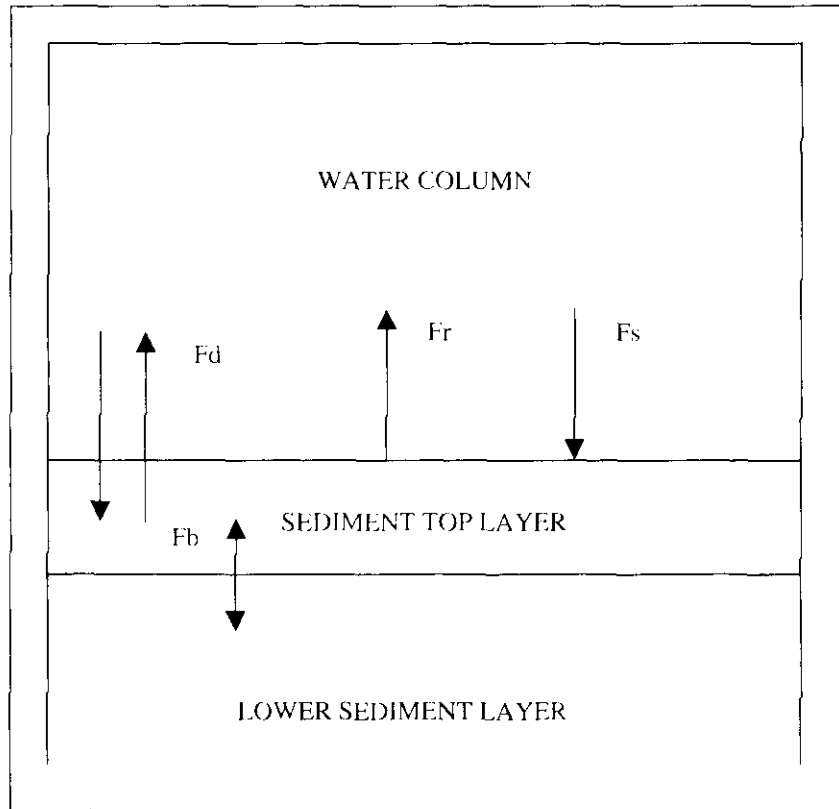


Figure B-1 Sediment model concept

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:

$$DX_w = f_{dxw} TX_w \quad (B-7)$$

$$PX_w = (1 - f_{dxw}) \frac{TX_w}{SS_w} \quad (B-8)$$

$$DX_b = f_{dxb} \frac{TX_w}{POR} \quad (B-9)$$

$$PX_b = (1 - f_{dxb}) \frac{TX_b}{SS_b} \quad (B-10)$$

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:**

$$F_{XD} = \frac{E_{diff}}{HB} (D_{XB} - D_{XW}) \quad (B-11)$$

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:**

$$F_{XS} = F_{sed} P X_W + v_s P O R D X_W \quad (B-12)$$

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:**

$$F_{XR} = F_{res} P X_B + v_r P O R D X_B \quad (B-13)$$

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:**

$$F_{XB} = -v_{sd} T X_B \quad \text{if } v_{sd} < 0 \quad (B-14)$$

or:

$$F_{XB} = -v_{sd} T X_{LB} \quad \text{if } v_{sd} < 0 \quad (B-15)$$

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:

$$\frac{dX_W}{dt} = \frac{F_{XD} - F_{XS} + F_{XR}}{Z} + P_{XW} \quad (B-16)$$

and:

$$\frac{dX_B}{dt} = \frac{F_{XD} - F_{XS} + F_{XR} + F_{XB}}{HB} + P_{XB} \quad (B-17)$$

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:

$$F_{XD} = \frac{E_{diff}}{HB} (X_I - X_W) \quad (B-18)$$

$$F_{XS} = v_s POR X_w \quad (B-19)$$

$$F_{XR} = v_r POR X_l \quad (B-20)$$

$$F_{XB} = -v_{sd} X_B \text{ if } v_{sd} > 0 \quad (B-21)$$

or

$$F_{XB} = v_{sd} X_{LB} \text{ if } v_{sd} < 0 \quad (B-22)$$

The concentration in the interstitial water in this case is represented by X_l 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:

$$\frac{dA_{w,i}}{dt} = [\mu_{max,i} F_{T,i} F_{N,i} F_{L,i} |A_{w,i} - \{K_{die,i} + k_{res,i} \theta_{ra,i}^{(T-20)} - \frac{v_{sa,i}}{Z}\}] A_{w,i} \quad (B-23)$$

The growth is considered to be limited by nutrients, light and temperature.

Nutrient limitation is described as:

$$F_{Ni} = \min \left[\frac{DIP_w}{DIP_w + k_{p,i}}, \frac{DIN_w}{DIN_w + k_{ni}} \right] \quad (B-24)$$

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:

$$F_{Li} = \frac{ef}{\epsilon_{tot} Z} [\exp(-\alpha_{ti}) - \exp(-\alpha_{ti})] \quad (B-25)$$

in which:

$$\alpha_{ti} = \frac{I_a}{I_{vi}} \quad (B-26)$$

and:

$$\alpha_{i,z} = \alpha_{i,0} \exp(-\epsilon_{i,0} Z) \quad (\text{B-27})$$

I_z 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.

$$\epsilon_{tot} = \epsilon_w + \epsilon_{chl} Chl - a + \epsilon_{SS} SS \quad (\text{B-28})$$

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:

$$Chl - a = \sum_{i=1}^n a_{chl:biom,i} A_{w,i} \quad (\text{B-29})$$

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:

$$F_T = \frac{T_{opt} - T}{T_{opt} - T_{min}} \exp\left(1 - \frac{T_{opt} - T}{T_{opt} - T_{max}}\right) \quad (\text{B-30})$$

If the water temperature is above the critical temperature for growth

$$F_T = 0.$$

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:

$$\frac{dA_B}{dt} = -K_{dieB} \theta^{T-20} A_B \quad (\text{B-31})$$

- 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 $f_{org,w}$. The following equation is used to describe the total organic phosphorus concentration in the water column:

$$\frac{dTOP_w}{dt} = -K_{dieB} \theta^{T-20} TOP_w + f_{org,w} a_p \sum_{i=1}^n [(K_{die,i} + K_{die,i} \theta_{i,0}) A_{w,i}] \quad (\text{B-32})$$

In the sediment organic phosphorus is only subject to anaerobic decomposition. The total organic phosphorus in the sediment top layer is given by:

$$\frac{dTOP_B}{dt} = -K_{minB} \theta_{minB}^{(T-20)} TOP_B + a_{pc} K_{daB} \theta_{daB}^{(T-20)} A_B \quad (B-33)$$

- Inorganic Phosphorus

The equations describing the inorganic phosphorus concentration in the water column and the sediment top layer are given by:

$$\begin{aligned} \frac{dTIP_W}{dt} = & K_{min} \theta_{min}^{(T-20)} TOP_W - a_{pc} \sum_{i=1}^3 [\mu_{max,i} F_{Ti} F_{Ni} F_{Li} A_{Wi}] \\ & + (1 - f_{porg}) a_{pc} \sum_{i=1}^3 [(K_{de,i} + K_{res,i} \theta_{ra,i}^{(T-20)}) A_{Wi}] \end{aligned} \quad (B-34)$$

and:

$$\frac{dTIP_B}{dt} = K_{minB} \theta_{minB}^{(T-20)} TOP_B \quad (B-35)$$

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:

$$f_{dpW} = \frac{1}{1 + K_{pipW} SS_W} \quad (B-36)$$

$$f_{dpB} = \frac{1}{1 + K_{pipB} SS_B} \quad (B-37)$$

The use of equations B-36 and B-37 implies that it 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:

$$\frac{dTON_W}{dt} = -K_{min} \theta_{min}^{(T-20)} TON_W + f_{nox} a_{nc} \sum_{i=1}^3 [(K_{de,i} + K_{res,i} \theta_{ra,i}^{(T-20)}) A_{Wi}] \quad (B-38)$$

$$\frac{dTON_B}{dt} = -K_{minB} \theta_{minB}^{(T-20)} TON_B + a_{nc} K_{daB} \theta_{daB}^{(T-20)} A_B \quad (B-39)$$

- 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:

$$P_{NH_4} = NH4_w \frac{NO3_w}{(K_{mN} + NH4_w)(K_{mN} + NO3_w)} + NH4_w \frac{K_{mN}}{(NH4_w + NO3_w)(K_{mN} + NO3_w)} \quad (B-40)$$

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_{mO} the rate can be limited at low oxygen concentrations. The equation for ammonia nitrogen in the water column is given by:

$$\frac{dNH4_w}{dt} = -K_{nut} \theta^{T-20} \frac{O2_w}{(O2_w + K_{mO})} NH4_w + K_{nut} \theta^{T-20} TON_w - a_m P_{NH_4} \sum_{i=1}^n [\mu_{max,i} F_{Ti} F_{Ni} F_{Li} A_{wi}] + a_m \sum_{i=1}^n [K_{d,i} + k_{d,i} \theta^{T-20}] \quad (B-41)$$

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:

$$\frac{dNH4_B}{dt} = K_{nut} \theta^{T-20} TON_B \quad (B-42)$$

- 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:

$$\frac{dNO3_w}{dt} = -K_{den} \theta^{T-20} \frac{K_{den}}{(K_{den} + O2_w)} NO3_w + K_{nut} \theta^{T-20} \frac{O2_w}{(O2_w + K_{mO})} NH4_w - a_m (1 - P_{NH_4}) \sum_{i=1}^n [\mu_{max,i} F_{Ti} F_{Ni} F_{Li} A_{wi}] \quad (B-43)$$

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:

$$\frac{dNO3_B}{dt} = -K_{denB} \theta^{T-20} NO3_B \quad (B-44)$$

- Chod

Because in practice 5 day carbon bod values are used, the equation describing the BOD concentration are expressed in BOD₅. In the oxygen balance equation (eq. B-48) however the ultimate BOD is used. A conversion factor is used to calculate BOD₅ from BOD_u. The BOD₅, which is produced by die-off of the algae and the BOD₅ used as a carbon source during denitrification is corrected using this conversion factor. The conversion factor is given by:

$$X_{conv} = 1 - \exp(-5K_{bod}^{20}) \quad (B-45)$$

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 BOD₅ is given by:

$$\frac{dBOD_W}{dt} = -K_{bod} \theta^{(T-20)} \frac{O2_W}{(O2_W + K_{boda})} BOD_W + \left[a_{oc} \sum_{i=1}^3 [K_{die,i} A_{Wi}] - \frac{5}{4} \frac{32}{14} K_{den} \theta^{(T-20)} \frac{K_{dno}}{(K_{dno} + O2_W)} NO3_W \right] X_{conv} \quad (B-46)$$

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 BOD₅ is given by:

$$\frac{dBOD_B}{dt} = \frac{a_{oc} K_{dab} \theta^{(T-20)} A_B - \frac{5}{4} \frac{32}{14} K_{denitB} \theta^{(T-20)} NO3_B}{X_{conv}} - K_{bodB} \theta^{(T-20)} BOD_B \quad (B-47)$$

Oxygen

Dissolved oxygen in the water column is described by:

$$\frac{dO2_W}{dt} = K_{re} \theta^{(T-20)} (C_s - O2_W) - K_{BOD} \theta^{(T-20)} \frac{O2_W}{(O2_W + K_{boda})} \frac{BOD_W}{X_{conv}} - \frac{64}{14} K_{nit} \theta^{(T-20)} \frac{O2_W}{(O2_W K_{NO})} NH4_W - \frac{32}{12} \sum_{i=1}^3 [K_{resi} \theta^{(T-20)} A_{Wi}] + \sum_{i=1}^3 [\mu_{max,i} F_{Ti} F_{Ni} F_{Li} A_{Wi}] \left[\frac{32}{12} + \frac{48}{12} a_{nc} (1 - P_{nh4}) NO3_W \right] \quad (B-48)$$

Additional to the oxidation of carbon BOD algal respiration and nitrification are included as oxygen consuming processes.

Reaeration is described using an empirical equation for the mass transfer coefficient. This coefficient is related to the flow velocity and water depth using:

$$k_{mas} = 3.94u^{0.5} z^{-1.5} \quad (B-49)$$

or if $k_{mas} < k_{rmin}$

$$k_{mas} = k_{rmin} \quad (B-50)$$

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 transfer coefficient. The reaeration constant k_r is given by:

$$k_r = \frac{k_{max}}{Z} \quad (B-51)$$

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:

$$\frac{d(O2)_B}{dt} = -K_{BODB} \theta^{(T-20)} \frac{BOD_B}{X_{crit}} \quad (B-52)$$

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 or 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:

$$SOD = \frac{E_{diff}}{HB} (O2_w - O2_B) \quad (B-53)$$

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}	Chlorophyll to carbon ratio species 1	$\mu g\ Chl / \mu g\ C$	30.000
a_n	Nitrogen to carbon ratio	$mg\ N / mg\ C$	0.25
a_o	Oxygen to carbon ratio	$mg\ O / mg\ C$	2.670
a_p	Phosphorus to carbon ratio	$mg\ P / mg\ C$	0.025
BOD_{1B}	BOD concentration lower sediment layer	$mg\ O_2 / l$	3500.0
e_b	Background extinction	$1/m$	1.0
e_{chl}	Specific extinction chlorophyll	$\mu g\ Chl / l / l \cdot m$	0.016
E_{diff}	Diffusive exchange rate constant	m/d	0.0002
e_{ss}	Specific extinction suspended solids	$mg\ SS / l \cdot m$	0.05
f_{dBODB}	Fraction dissolved BOD sediment	-	0.03
f_{dBODW}	Fraction dissolved BOD water column	-	0.90
f_{dONB}	Fraction dissolved organic nitrogen sediment	-	0.10
f_{dONW}	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
$f_{n,n}$	Fraction algal nitrogen released as organic nitrogen	-	0.50
$f_{p,p}$	Fraction algal phosphorus released as organic phosphorus	-	0.50
HB	Depth of the sediment top layer	m	0.10
I	Optimal light intensity species 1	W/m	40.0
$K_{1,w}$	Oxidation rate constant BOD water column	$1/d$	0.10
$K_{1,sdB}$	Anaerobic decomposition rate constant BOD sediment	$1/d$	0.005
$K_{1,sdB}$	Oxygen half saturation constant BOD decay	$mg\ O_2 / l$	2.0
$K_{1,dB}$	Anaerobic decay rate constant algae sediment	$1/d$	0.010
$K_{1,dw}$	Denitrification rate constant water column	$1/d$	0.10
$K_{1,dw}$	Denitrification rate constant sediment	$1/d$	0.10
$K_{1,dw}$	Die-off rate constant species 1	$1/d$	0.10

K_{2m}	Oxygen half saturation constant denitrification	mg O ₂ /l	0.50
K_{Tm}	Decomposition rate constant organic matter water column	1/d	0.10
K_{TmB}	Anaerobic decomposition rate constant sediment	1/d	0.001
K_{im}	Ammonia preference constant	mg N/l	0.025
$k_{T,i}$	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_{PmB}	Partition coefficient inorganic phosphorus sediment	l/mg SS	0.00250
K_{PmW}	Partition coefficient inorganic phosphorus water column	l/mg SS	0.05000
$k_{res,i}$	Respiration rate constant species i	1/d	0.05000
k_{min}	Minimum oxygen transfer coefficient	m/d	0.40000
NH ₄ _{1,B}	Ammonia concentration lower sediment layer	mg N/l	1.600
NO ₃ _{1,B}	Nitrate concentration lower sediment layer	mg N/l	0.000
O ₂ _{1,B}	Oxygen (equivalents) concentration lower sediment	mg O ₂ /l	0.000
POR	Sediment porosity	-	0.8
ρ	Density suspended solids	kg/m ³	1320
$\theta_{1,ox}$	Temperature coefficient oxidation BOD	-	1.04
$\theta_{1,deB}$	Temperature coefficient decomposition BOD sediment	-	1.08
$T_{c,i}$	Critical temperature species i	°C	35.0
$\theta_{1,de}$	Temperature coefficient anaerobic decomposition sediment	-	1.080
$\theta_{1,den}$	Temperature coefficient denitrification water column	-	1.040
$\theta_{1,denB}$	Temperature coefficient denitrification sediment	-	1.040
TIP _{1,B}	Total inorganic phosphorus lower sediment layer	mg P/l	1.900
$\theta_{1,min}$	Temperature coefficient mineralisation water column	-	1.040
$\theta_{1,minB}$	Temperature coefficient mineralisation sediment	-	1.080
$\theta_{1,nit}$	Temperature coefficient nitrification	-	1.080
TON _{1,B}	Total organic nitrogen lower sediment layer	mg N/l	15.000
TOP _{1,B}	Total organic phosphorus lower sediment layer	mg P/l	5.000
$T_{opt,i}$	Optimal temperature species i	°C	20.0
$\theta_{res,i}$	Temperature coefficient respiration species i	-	1.040
θ_{res}	Temperature coefficient reaeration	-	1.024
$\mu_{max,i}$	Maximum growth rate species i	1/d	1.200
$v_{s,i}$	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 in 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.

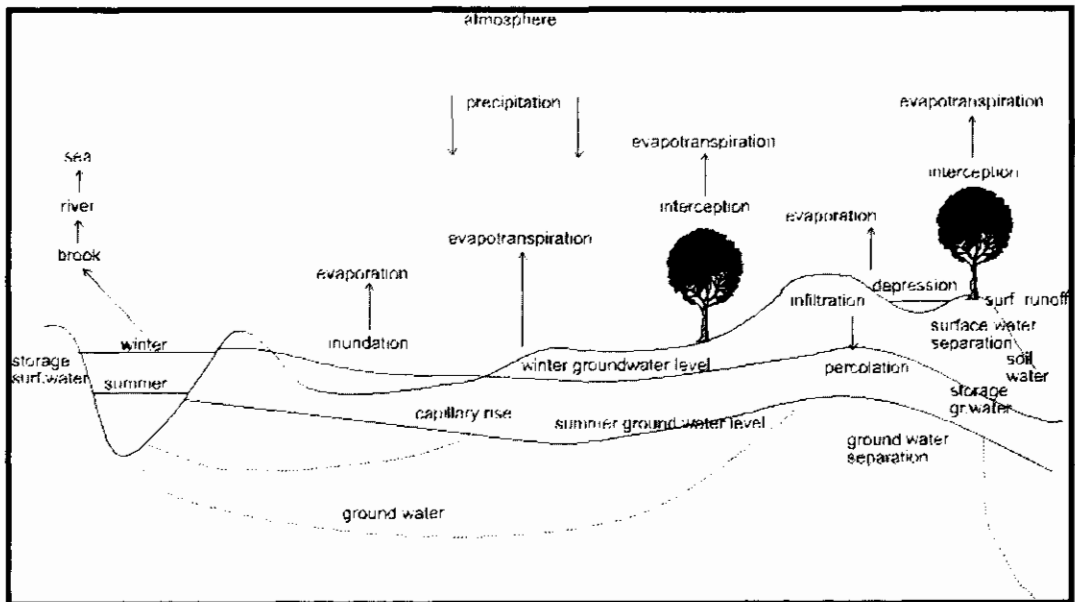
Symbol	Description	Dimension	Range
NH _{4I}	Interstitial ammonia concentration	mg N/l	0.2-5.0
NO _{3I}	Interstitial nitrate concentration	mg N/l	0.0-0.1
DIP _B	Interstitial inorganic phosphorus	mg P/l	0.0-0.1
PIP _B	Particulate inorganic phosphorus	mg P/g SS	0.0-3.0
TON _B	Total organic nitrogen		0.5-5 % 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

Reference Manual

VERSION 3.3 April 2000

Stowa / EDS



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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*.

2. Theoretical System Description

2.1 Introduction

Insight into the various hydrologic processes is necessary for a correct description of the precipitation runoff processes. The same applies to giving a correct description of runoff and leaching, which requires insight into the mass balances.

Preceding the Formulas, the hydrologic cycle (section 2.2) and the nitrogen and phosphor balances (section 2.2) are explained in this chapter. It is not intended to give an exhaustive explanation (for this reason the literature is referred to). But, a short description that is sufficient as reference for this manual.

Precipitation runoff processes are generally described at a catchment area level. Within a catchment area, the relevant parameters may vary substantially (soil type, slope, land use, etc.). A detailed physical description of the occurring processes is, therefore, difficult to give. In the literature, the hydrologic cycle is generally described as a chain of processes (indicating the course of processes and quantifying the amounts by means of water balances). This also applies to mass balances. In this chapter, this point of view is the point of departure.

2.2 Hydrologic Cycle

The Hydrologic Cycle is a continuous process in which water circulates from the oceans through the atmosphere and the rivers back to the ocean. In figure 1 the hydrologic cycle is outlined in a schematic cross section. The various processes are reflected in a flow chart in figure 2.

Ocean water evaporates into the atmosphere. This water falls as precipitation partly on the land surface and partly on the sea surface. The precipitation that falls on the land surface, is stored temporarily on vegetation (interception), on objects, on the surface (depressions), in the soil (replenishment of soil moisture and ground water reservoir) and in open waters. The surplus precipitation, this is the precipitation that does not evaporate eventually, will end up running off as ground water or surface water eventually (Van Dam, 1991).

Before precipitation is discharged, it goes through various processes. Part of the precipitation will evaporate. The amount of precipitation that is drained during a time interval, cannot be put on a par with the difference between the precipitation and the evaporation, due to the buffer effect of the terrain, the subsoil and the drainage system. This buffer effect, which is the resultant of a number of reservoir effects of different natures and sizes, leads to time shifts between the

amounts of precipitation, evaporation and discharge belonging together. The larger a time interval is taken and, therefore, the smaller the total reservoir effect is, the more the discharge will approach the difference between precipitation and evaporation. The total storage effect is, however, important to the determination of a flood wave (relatively short period of time), due to quelling and slowing down of the precipitation surplus. The storage effects are less important to the total drainage during a longer period of time, but are aimed at determining the items in the water balance (Warmerdam, 1994).

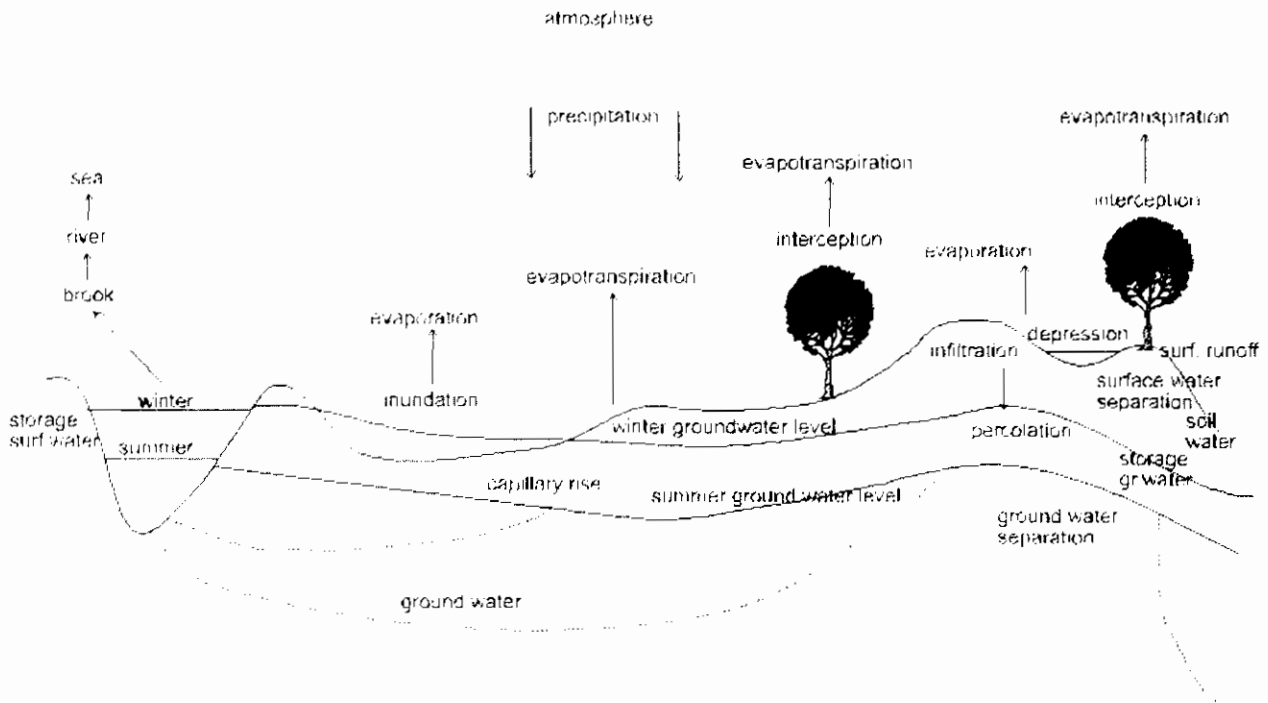


figure 1: Hydrologic cycle (Warmerdam, 1994)

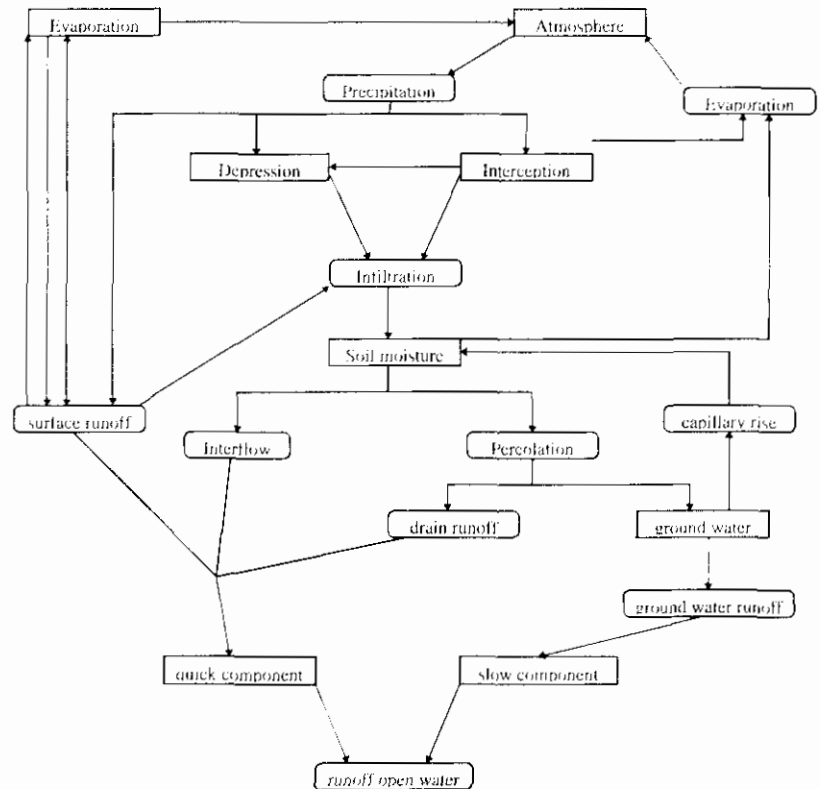


figure 2: Hydrologic cycle flow chart

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.

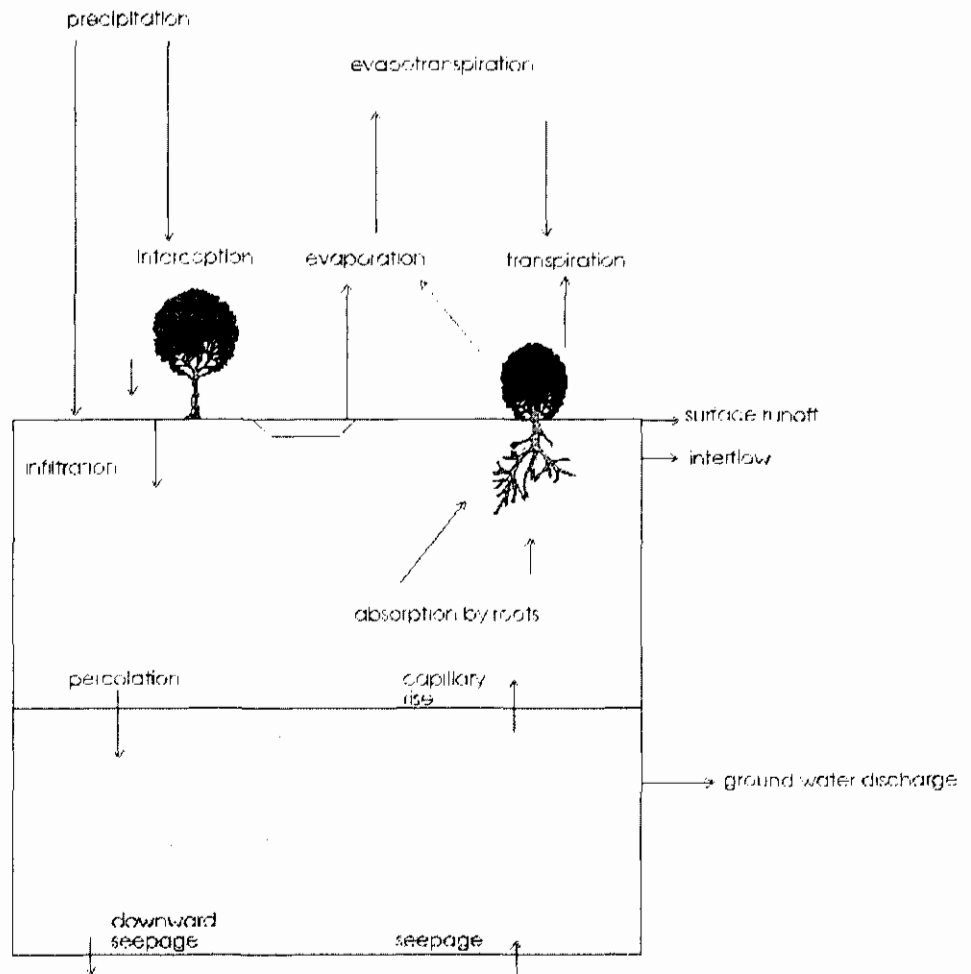


figure 3: Hydrologic processes unpaved surface

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.

quick ground water discharge

slow ground water discharge

figure 4: Quick and slow components of ground water discharge

Q

Q_{total}

quick component

slow component

t

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:

$$\text{Incoming terms} = \text{Outflowing terms} + \text{Change in storage in the area}$$

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.

$$P + Q_i + K = Q_o + E + W + \Delta S$$

In which

P : precipitation in mm

Q_i : incoming flows in mm (originating from adjoining catchment areas)

Q_o : outgoing flows in mm

K : seepage in mm

E : evapotranspiration in mm

W : downward seepage in mm

ΔS : 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.

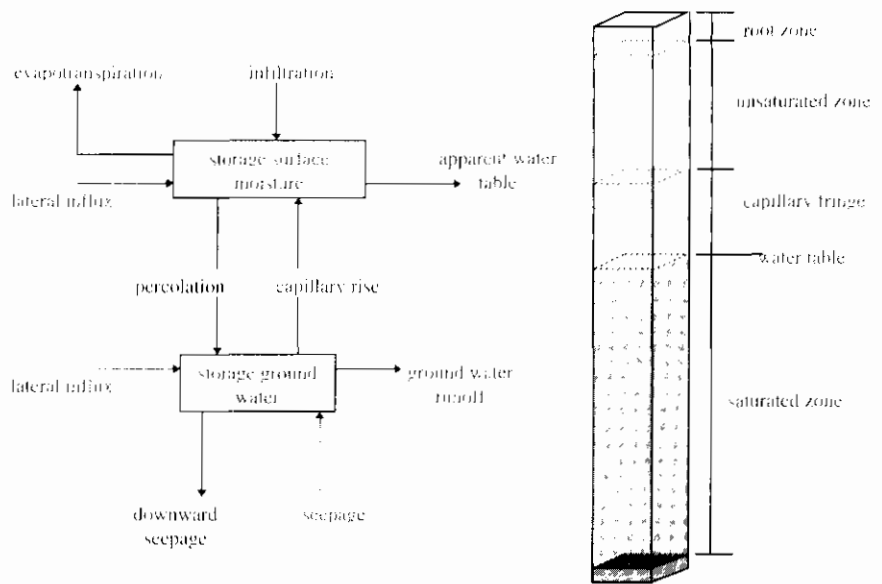


Figure 6: Schematic overview terms water balance

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:

$$Q_{percolation} + Q_{li} - Q_{capillary} + K + W \cdot \Delta S_{saturated}$$

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.

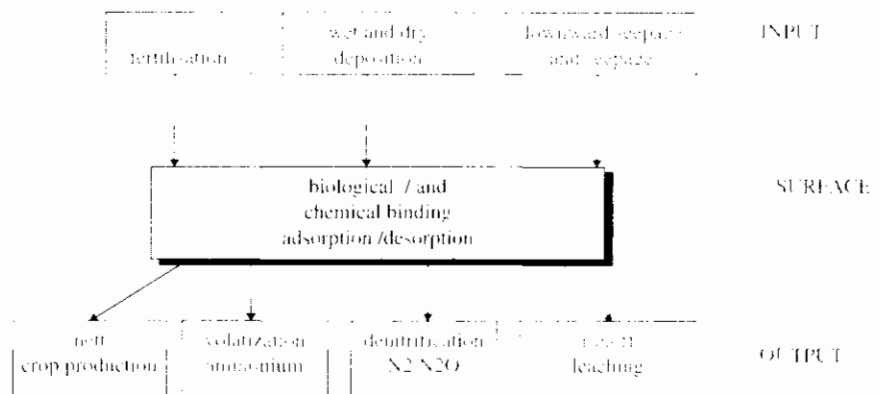


figure 7: N- and P balances of a ground water system (Hoeks et al., 1990).

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:	(87%)	(99%)
• Manure	(44%)	(74%)
• Fertilizer	(43%)	(25%)
Deposition:	(13%)	(<1%)
• Wet deposition	(5%)	
• Dry deposition	(8%)	
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.

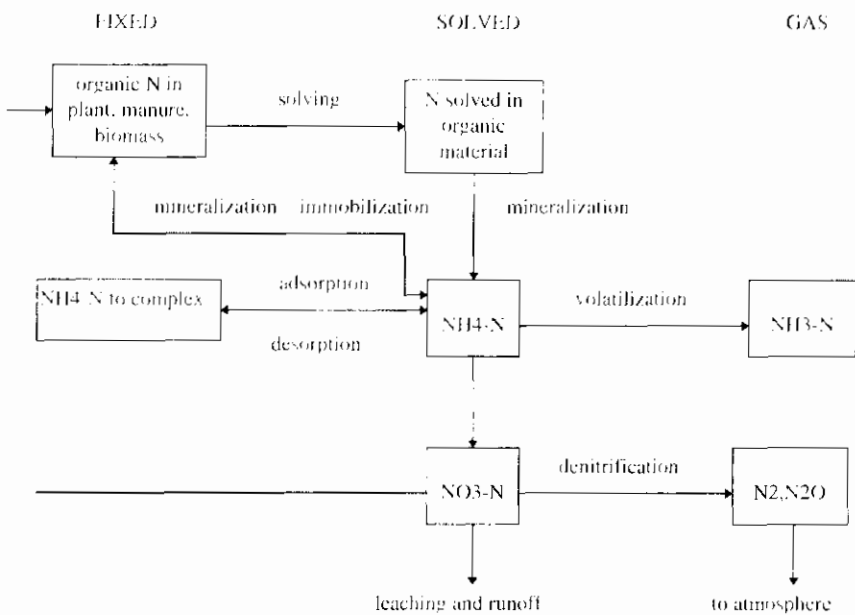


figure 8: Schematic overview of the nitrogen balance in the ground

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 formedIn the soil, ammonium is converted into nitrate by so-called nitrifying bacteria:



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 $\text{NO}_3^-/\text{N/l}$ 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.

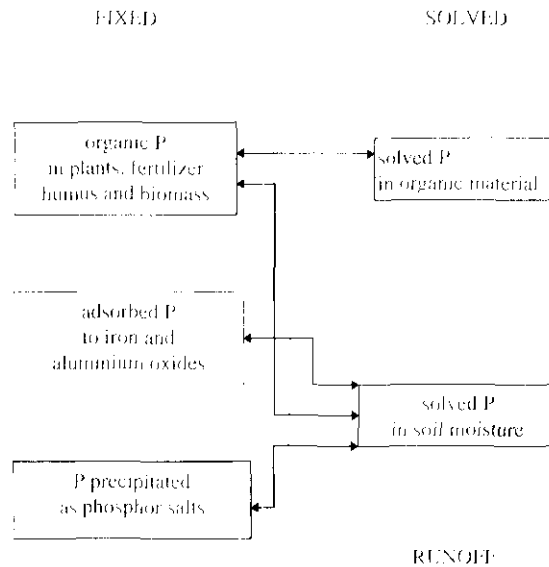


figure 9: phosphor balance in the ground

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 adsorbs/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 into 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.

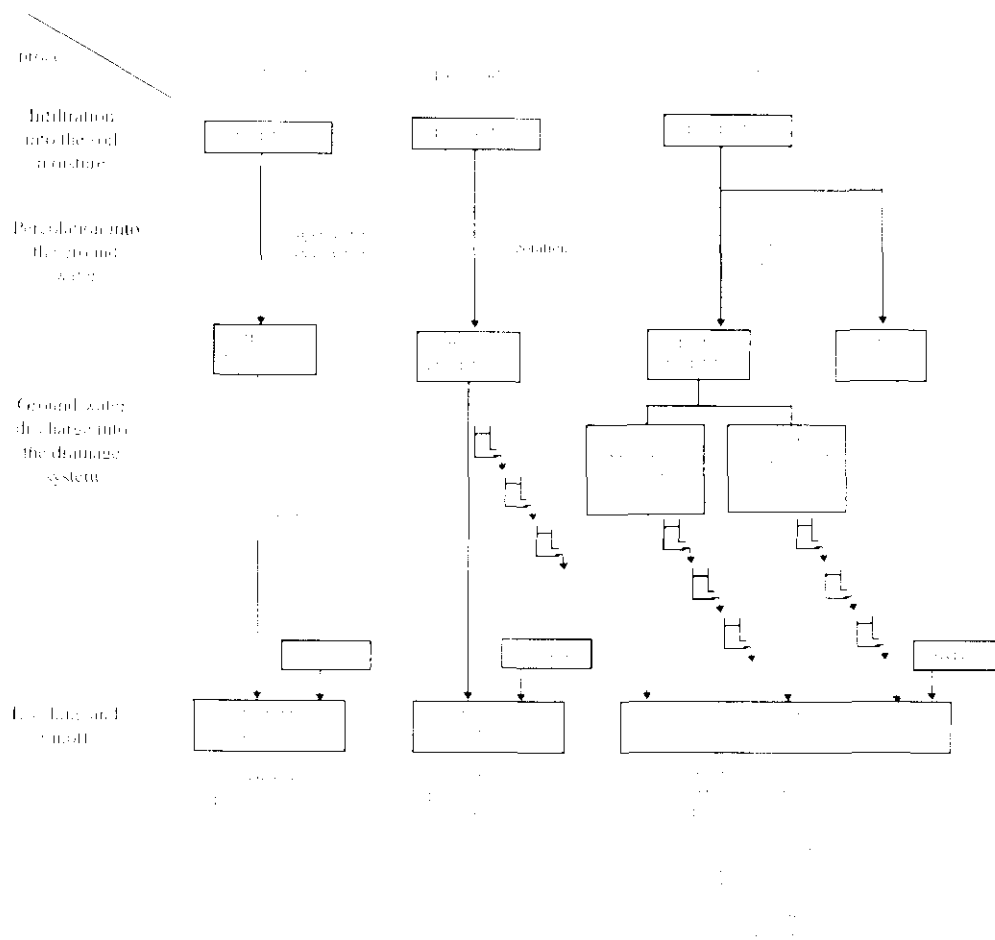


figure 10: Framework of the precipitation runoff module

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

- Urban area;
- Greenhouse area.

The discharge from paved surface is therefore divided into three subflows:

1. Paved surface discharging directly through the drainage system;
2. Surface discharging through a separated sewer system.
3. Surface covered with greenhouses

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).

A percentage of the surface can be defined to be open. In that case a part of the water will infiltrate to the unsaturated zone. The discharge of the infiltrated water is treated by the unpaved area part.

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 can be treated. The discharge from a sewer system is modeled by means of a storage capacity in the sewer system and a pump over capacity.

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.

Just like the paved surface the user can define a percentage of the surface to be open. In that case a part of the water will infiltrate to the unsaturated zone. The discharge of the infiltrated water is treated by the unpaved area part.

3.2.3 Greenhouse area

The crop in greenhouses needs water. This water can be supplied in two ways. First from a reservoir in which the precipitation is kept and second by supply from a drink water company.

The discharge from greenhouse areas may be entered directly under subflow 3 (greenhouse surface).

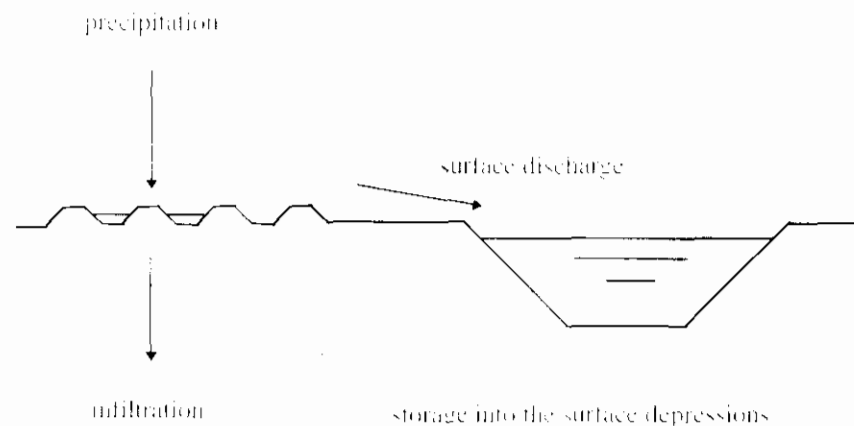
3.3 Unpaved surface

For the runoff processes of unpaved surface, three processes were distinguished in the precipitation runoff module (see section 2.2.2):

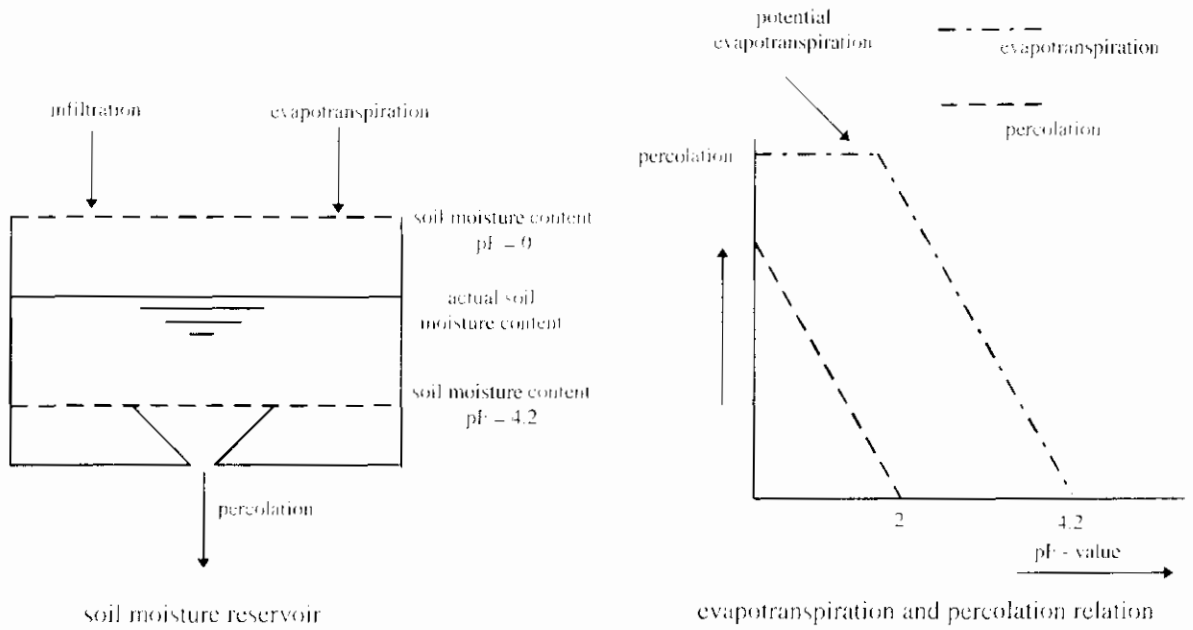
1. Infiltration into the soil moisture (unsaturated zone)
2. Percolation into the ground water (saturated zone)
3. Ground water discharge into the drainage system.

These processes are distinguished in the precipitation runoff module also. This set up is reflected in figure 11.

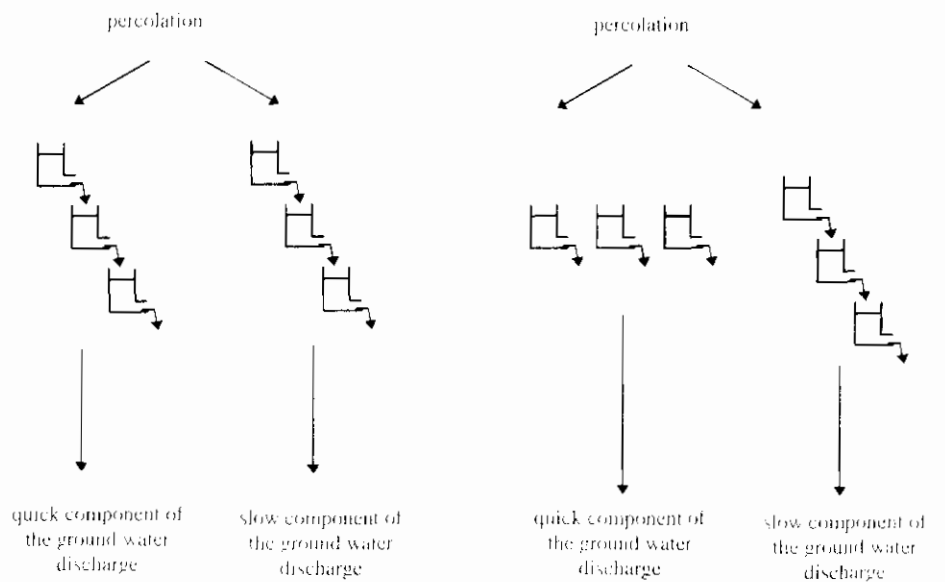
process A. Infiltration into the soil moisture



process B. Percolation into the ground water



process C. Ground water discharge into the drainage system



Option 1: two parallel Nash-cascades

option 2: Combination Nash-cascade - Krayenhoff van de Leur

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 than 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 from 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 from 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 ($Q_{\text{open water}}$);
- 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_{surf});
- Quick component ground water discharge (Q_{qgw});
- Slow component ground water discharge (Q_{sgw});

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 momentaneous discharge at the end of the time interval defined at point of time t (unit: [m³/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:

$$P_{N,open_water,t} = P_{b,t} - f_0 E_{r,t} \quad (1)$$

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.

$$q_{open_water,t} = q_{open_water,t-1} e^{-\Delta t / k_0} + P_{N,open_water,t} (1 - e^{-\Delta t / k_0}) \quad (2-a)$$

$$Q_{open_water,t} = a \lambda_{open_water} q_{open_water,t} \quad (2-b)$$

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	$Q_{open_water,t}$	[m ³ /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:

$$S_{NH4-N,open_water,t} = Q_{open_water,t} \times C_{NH4-N,precipitation,t} \quad (3-a)$$

$$S_{NO3-N,open_water,t} = Q_{open_water,t} \times C_{NO3-N,precipitation,t} \quad (3-b)$$

Input	$Q_{open_water,t}$	[m ³ /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	$Q_{open_water,t}$	[m ³ /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

For all surface types one method is used for modelling the precipitation loss. The precipitation is collected in a reservoir, which is the storage of the paved surface, from which evaporation and infiltration takes place. The precipitation which cannot be stored, infiltrated or evaporated is discharged as surface runoff and forms the input for the discharge retardation model.

Because of the difference of storage and infiltration depending on the type of the surface a distinction is made between open paved surface and closed paved surface. For each type of paved surface the evaporation is set equal to the open water evaporation according to Pennmann. All surface runoff is discharged.

Effective precipitation at open paved surface

The precipitation loss of open paved surface is determined by three processes: evaporation, infiltration and storage. The storage is considered as a reservoir from which evaporation and infiltration take place. The infiltration at open paved

surfaced is described with a constant infiltration intensity: the infiltration capacity (same as infiltration in unpaved surface).

In general it can be stated that a constant infiltration intensity is reached within 24 hours. The here introduced error is limited at timesteps of more than one day. The infiltration intensity is calculated over the timestep t_{i-1} tot t_i . The rainfall intensity (over the time step) minus the evaporation (over the time step) is added to the available storage at the surface at the start of the timestep.

If the rainfall intensity and the available storage minus the evaporation are larger than the infiltration capacity, the infiltration intensity is set equal to the infiltration capacity. The infiltration capacity varies with time and is given in formula 5.

$$I_{o,t} = P_{b,t} - f_o E_{r,t} + \frac{B_{o,t-1}}{\Delta t} \quad \text{if } P_{b,t} \Delta t + B_{o,t-1} \geq f_o E_{r,t} \Delta t \text{ and} \quad (5-a)$$

$$\text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{o,t-1}}{\Delta t} \leq I_{o,max}$$

$$I_{o,t} = I_{o,max} \quad \text{if } P_{b,t} \Delta t + B_{o,t-1} \geq f_o E_{r,t} \Delta t \text{ and} \quad (5-b)$$

$$\text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{o,t-1}}{\Delta t} > I_{o,max}$$

$$I_{o,t} = 0 \quad \text{if } P_{b,t} \Delta t + B_{o,t-1} < f_o E_{r,t} \Delta t \quad (5-c)$$

Input	$P_{b,t}$ $B_{o,t-1}$ $E_{r,t}$	[mm/day] [mm] [mm/day]	precipitation intensity storage at open paved surface (formula 7) reference crop evaporation Makkink
Model parameters	$I_{o,max}$ f_o t	[mm] [-] [day]	infiltration capacity crop factor Makkink open water Timestep
output	$I_{o,t}$	[mm/day]	infiltration intensity

* For $B_{o,t-1}$ at timestep $t=0$ the value equals 0, resembling a situation without surface storage.

** The crop factor for open water equals E_o/E_r , where E_o is the open water evaporation according to Penmann. The factor varies a little, but is set equal to 1.25.

Formula 2 gives the maximum infiltration capacity at time step t according to Horton.

The formule for the reduction in infiltration capacity applies when the precipitation intensity surpasses the infiltration capacity of the soil and as long water is present at the surface (in depressions). The formule for recovery of the infiltration capacity applies as long the surface is dry. From the moment the surface storage is empty the formula for the recovery of the infiltration capacity applies until the maximum infiltration capacity is reached.

$$I_{o,max,t} = I_e + (I_b - I_e) e^{-k_o t} \quad \text{if } I_{o,max,t} = I_b \text{ or} \quad (6-a)$$

$$\text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{o,t-1}}{\Delta t} > 0$$

$$I_{o,max,t} = I_b - (I_b - I_e) e^{-k_o t} \quad \text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{o,t-1}}{\Delta t} \leq 0 \quad (6-b)$$

Input	$P_{b,t}$	[mm/day]	precipitation intensity
	$E_{r,t}$	[mm/day]	reference crop evaporation according to Makkink
	$B_{b,t-1}$	[mm]	storage at open paved surface (formula 7)
Model parameters	$I_{b,max,t}$	[mm/day]	maximum infiltration intensity at timestep t (formula 6)
	$I_{b,max,0}$	[mm/day]	maximum infiltration intensity at timestep 0
	I_b	[mm/day]	maximum infiltration capacity
	I_c	[mm/day]	minimum infiltration capacity
	Δt	[day]	time step
	k_r	[1/day]	time factor for reduction infiltration capacity
	k_h	[1/day]	time factor for enlarging infiltration capacity
	f_o	[-]	crop factor Makkink for open water
output	$I_{b,max,t}$	[mm/day]	maximum infiltration at time step t

If the precipitation intensity minus the evaporation surpasses the infiltration capacity, the water is stored in surface depressions (precipitation pools). The precipitation thus stored will eventually evaporate or infiltrate, or will be discharged as surface runoff. The storage at time t is determined with a water balance for storage at the surface. Therefor the precipitation intensity (after evaporation) minus the infiltration intensity during the interval t-1 to t is added to the present storage at the surface at the start of the interval (time t-1). When the maximum storage is reached surface runoff starts. Therefor the storage is set equal to the maximum storage at the surface.

$$B_{b,t} = 0 \quad \text{if } P_{b,t} \Delta t + B_{b,t-1} < f_o E_{r,t} \Delta t \text{ en} \quad (7-a)$$

$$\text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{b,t-1}}{\Delta t} \leq I_{b,max}$$

$$B_{b,t} = (P_{b,t} - f_o E_{r,t} - I_{b,t}) \Delta t + B_{b,t-1} \quad (7-b)$$

$$\text{if } P_{b,t} \Delta t + B_{b,t-1} \geq f_o E_{r,t} \Delta t \text{ and}$$

$$\text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{b,t-1}}{\Delta t} > I_{b,max} \text{ and}$$

$$\text{if } (P_{b,t} - f_o E_{r,t} - I_{b,t}) \Delta t + B_{b,t-1} \leq B_{b,max}$$

$$B_{b,t} = B_{b,max} \quad \text{if } P_{b,t} - f_o E_{r,t} + \frac{B_{b,t-1}}{\Delta t} > I_{b,max} \quad (7-c)$$

$$\text{if } (P_{b,t} - f_o E_{r,t} - I_{b,t}) \Delta t + B_{b,t-1} > B_{b,max}$$

Input	$P_{b,t}$	[mm/day]	precipitation intensity
	$I_{b,t}$	[mm/day]	infiltration intensity (formula 5)
	$B_{b,t-1}$	[mm]	storage at open paved surface (formula 7)
	$E_{r,t}$	[mm/day]	reference crop evaporation according to Makkink
model parameters	$I_{b,max,t}$	[mm/day]	infiltration capacity
	$B_{b,max}$	[mm]	maximum storage at paved surface
	f_o	[-]	crop factor Makkink for open water
	Δt	[day]	time step
output	$B_{b,t}$	[mm]	storage at open paved surface

For $B_{b,t}$ at time step t=0 a value of 0 is taken, according a situation without surface storage.

The amount of precipitation discharging as surface runoff, is depending on the infiltration capacity of the open paved surface, the precipitation intensity and the

storage in terrain depressions. When part of the storage surpasses the maximum storage, surface runoff starts.

$$P_{N,t} = P_{b,t} - f_o E_{r,t} + \frac{B_{o,t-1} - I_{o,t} - B_{v,max}}{\Delta t} \quad \text{if } (P_{b,t} - f_o E_{r,t} - I_{o,t}) \Delta t + B_{o,t-1} > B_{v,max} \quad (8-a)$$

$$P_{N,t} = 0 \quad \text{if } (P_{b,t} - f_o E_{r,t} - I_{o,t}) \Delta t + B_{o,t-1} \leq B_{v,max} \quad (8-b)$$

Input	$P_{b,t}$	[mm/day]	precipitation intensity
	$I_{o,t}$	[mm/day]	infiltration intensity (formula 5)
	$B_{o,t-1}$ *	[mm]	storage at open paved surface (formula 7)
	$E_{r,t}$	[mm/day]	reference crop evaporation according to Makkink
model parameters	$B_{v,max}$	[mm]	maximum storage at surface
	f_o	[-]	crop factor Makkink for open water
	Δt	[day]	time step
output	$P_{N,t}$	[mm/day]	surface runoff at open paved surface

* For $B_{o,t}$ at time step $t=0$ the value 0 is used, according a situation without surface storage.

Effective precipitation at closed paved surface

The precipitation loss at closed paved surface is determined by two processes: evaporation and storage at the surface. The storage is modelled as a reservoir from which evaporation can take place. The precipitation is immediately stored. Depending on the precipitation at time t and the storage at time $t-1$ evaporation takes place.

In the case the evaporation in time step $t-1$ to t surpasses the sum of the precipitation in the same time step and the storage at time t , then the storage at time $t-1$ is set to zero.

When the rainfall minus the sum of evaporation and storage at time $t-1$ surpasses the maximum storage, the storage at time t is set equal to the maximum storage.

$$B_{g,t} = P_{b,t} \Delta t + B_{g,t-1} - f_o E_{r,t} \Delta t \quad \text{if } P_{b,t} \Delta t + B_{g,t-1} \geq f_o E_{r,t} \Delta t \quad \text{and} \quad (9-a)$$

$$\text{if } P_{b,t} \Delta t + B_{g,t-1} - f_o E_{r,t} \Delta t \leq B_{v,max} \quad (9-b)$$

$$B_{g,t} = 0 \quad \text{if } P_{b,t} \Delta t + B_{g,t-1} < f_o E_{r,t} \Delta t$$

$$B_{g,t} = B_{v,max} \quad \text{if } P_{b,t} \Delta t + B_{g,t-1} \geq f_o E_{r,t} \Delta t \quad \text{and} \quad (9-c)$$

$$\text{if } P_{b,t} \Delta t + B_{g,t-1} - f_o E_{r,t} \Delta t \geq B_{v,max}$$

Input	P_{net}	[mm/day]	precipitation intensity
	B_{closed}	[mm]	storage at closed surface (formula 9)
	E_{ref}	[mm/day]	reference crop evaporation according to Makkink
model parameters	B_{max}	[mm]	maximum storage at paved surface
	f_o	[-]	crop factor Makkink for open water
	Δt	[day]	time step
output	B_{closed}	[mm]	storage at closed surface

for B_{closed} at time $t=0$ the value is set to 0, according to a situation without storage at closed surface.

The quantity of precipitation discharged as surface runoff, is depending on the precipitation intensity, the evaporation and the storage at closed paved surface. When this quantity surpasses the maximum storage surface runoff starts.

$$P_{N_{net}} = P_{net} - f_o E_{ref} + \frac{B_{closed} - B_{max}}{\Delta t} \quad \text{if } (P_{net} - f_o E_{ref}) \Delta t + B_{closed} > B_{max} \quad (10-a)$$

$$P_{N_{net}} = 0 \quad \text{if } (P_{net} - f_o E_{ref}) \Delta t + B_{closed} \leq B_{max} \quad (10-b)$$

input	P_{net}	[mm/day]	precipitation intensity
	B_{closed}	[mm]	storage at closed paved surface (formula 9)
	E_{ref}	[mm/day]	reference crop evaporation according to Makkink
model parameters	B_{max}	[mm]	maximum storage at paved surface
	f_o	[-]	crop factor Makkink for open water
	Δt	[day]	time step
Output	$P_{N_{net}}$	[mm/day]	surface runoff at closed paved surface

4.3.2 Description of the Hydrograph

For the calculation of the discharge of surface runoff a distinction is made for open and closed paved surface. The following five surface types will be described: open paved surface with sewer system, closed paved surface with sewer system, greenhouse surface, other open paved surface and other closed paved surface.

Open paved surface with sewer system

The surface runoff flows retarded to the sewer system where it is stored. Part of the stored water will be pumped to a sewer treatment plant. If the quantity of surface runoff surpasses the storage capacity of the sewer system, the surface runoff is directed to open water.

$$P_{B_{net}} = P_{B_{net}} e^{-\frac{B_{closed}}{k}} + \left(\frac{A_{open}}{A_{open} + A_{closed}} P_{N_{net}} + \frac{A_{closed}}{A_{open} + A_{closed}} P_{N_{closed}} \right) (1 - e^{-\frac{B_{closed}}{k}}) \quad (11-a)$$

Input	$P_{B_{net}}$	[mm/day]	surface runoff on surface with sewer system (formula 11)
	$P_{N_{net}}$	[mm/day]	surface runoff on open paved surface (formula 8)
	$P_{N_{closed}}$	[mm/day]	surface runoff on closed paved surface (formula 10)
model parameters	k	[-]	time constant of reservoir
	Δt	[day]	time step
	A_{open}	[ha]	open paved surface
	A_{closed}	[ha]	closed paved surface
output	$P_{B_{net}}$	[mm/day]	surface runoff on surface with sewer system

$$B_{closed} = 0 \quad \text{if } P_{B_{net}} \Delta t + B_{closed} < p_{oc} \Delta t \quad (12-a)$$

$$B_{ra,t} = (P_{B,r,t} - p_{oc}) \Delta t + B_{ra,t-1} \text{ if } P_{B,r,t} \Delta t + B_{ra,t-1} \geq p_{oc} \Delta t \text{ and} \quad (12-b)$$

$$\text{if } (P_{B,r,t} - p_{oc}) \Delta t + B_{ra,t-1} < B_{ra,max}$$

$$B_{ra,t} = B_{ra,max} \quad \text{if } (P_{B,r,t} - p_{oc}) \Delta t + B_{ra,t-1} \geq B_{ra,max} \quad (12-c)$$

input	$P_{B,r,t}$	[mm/day]	surface runoff on surface with sewer system (formula 11)
	$B_{ra,t-1}$	[mm]	storage in sewer system (formula 12)
model parameters	p_{oc}	[mm/day]	pump over capacity
	Δt	[day]	time step
	$B_{ra,max}$	[mm]	maximum storage in sewer system
output	$B_{ra,t}$	[mm]	storage in sewer system

For $B_{ra,t-1}$ at time $t=0$ the value is set to 0, according to a situation without storage in sewer system.

$$q_{B,r,t} = P_{B,r,t} - p_{oc} + \frac{B_{ra,t-1} - B_{ra,max}}{\Delta t} \quad \text{if } (P_{B,r,t} - p_{oc}) \Delta t + B_{ra,t-1} \geq B_{ra,max} \quad (13-a)$$

$$q_{B,r,t} = 0 \quad \text{if } (P_{B,r,t} - p_{oc}) \Delta t + B_{ra,t-1} < B_{ra,max} \quad (13-b)$$

$$Q_{B,r,t} = a (A_{o,r} + A_{g,r}) q_{B,r,t} \quad (13-c)$$

input	$P_{B,r,t}$	[mm/day]	surface runoff (formula 11)
	$B_{ra,t-1}$	[mm]	storage in sewer system (formula 12)
	$q_{B,r,t}$	[mm/day]	specific discharge open paved surface (formula 13)
	$A_{o,r}$	[ha]	open paved surface with sewer system
	$A_{g,r}$	[ha]	closed paved surface with sewer system
model parameters	p_{oc}	[mm/day]	pump over capacity
	Δt	[day]	time step
	$B_{ra,max}$	[mm]	Maximum storage in sewer system
	a	[-]	Factor
output	$Q_{B,r,t}$	[m ³ /sec]	discharge from open paved surface with sewer system

Factor equals: 10/(24*3600).

greenhouse surface

For the discharge resulting from greenhouse surface two systems can be distinguished: discharge through storage and through direct discharge. For every applying node in RAM the user has to make a choice between these two systems (only if greenhouse surface). If no storage is available in the greenhouse area the value for maximum storage $B_{ka,max}$ is set to zero.

$$P_{B,k,t} = P_{B,r,t-1} e^{-\Delta t/L_k} + P_{N,r,t} (1 - e^{-\Delta t/L_k}) \quad (14)$$

Input	$P_{B,r,t-1}$	[mm/day]	surface runoff from closed paved surface with sewer system (formula 14)
	$P_{N,r,t}$	[mm/day]	precipitation intensity from closed paved surface (formula 12)
model parameters	k_k	[-]	Time constant reservoir
	Δt	[day]	Time step
output	$P_{B,k,t}$	[mm/day]	Surface runoff from greenhouse area

$$B_{ka,t} = 0 \quad \text{if } P_{B,k,t} \Delta t + B_{ka,t-1} < p_k \Delta t \quad (15-a)$$

$$B_{ka,t} = (P_{B,k,t} - p_k) \Delta t + B_{ka,t-1} \text{ if } P_{B,k,t} \Delta t + B_{ka,t-1} \geq p_k \Delta t \text{ and} \quad (15-b)$$

$$B_{k,t} = B_{k,max} \quad \text{if } (P_{B,t} - p_k) \Delta t + B_{k,t-1} \geq B_{k,max} \quad (15-c)$$

Input	$P_{B,k,t}$	[mm/day]	surface runoff from greenhouse area (formula 14)
model parameters	$B_{k,t-1}$	[mm]	storage in greenhouse area (formula 15)
	$B_{k,max}$	[mm]	maximum storage in greenhouse area
output	p_k	[mm/day]	pump capacity irrigation water
	Δt	[day]	time step
	$B_{k,t}$	[mm]	storage in greenhouse area

The precipitation intensity can be calculated from the storage.

$$q_{B,t} = (P_{B,t} - p_k) + \frac{B_{k,t-1} - B_{k,max}}{\Delta t} \quad \text{if } (P_{B,t} - p_k) \Delta t + B_{k,t-1} \geq B_{k,max} \quad (16-a)$$

$$q_{B,t} = 0 \quad \text{if } (P_{B,t} - p_k) \Delta t + B_{k,t-1} < B_{k,max} \quad (16-b)$$

$$Q_{B,t} = a (\Lambda_k q_{B,t}) \quad (16-c)$$

Input	$q_{B,t}$	[mm/day]	specific discharge greenhouse surface (formula 14)
model parameters	$B_{k,t-1}$	[mm]	storage in greenhouse area (formula 15)
	$P_{B,t}$	[mm/day]	surface runoff from greenhouse area (formula 14)
output	Λ_k	[ha]	greenhouse surface
	$B_{k,max}$	[mm]	maximum storage in greenhouse area
	p_k	[mm/day]	pump capacity irrigation water
	Δt	[day]	time step
	a	[-]	Factor
	$Q_{B,t}$	[m ³ /s]	discharge form greenhouse surface

other open paved surface

The retarded discharge from other open paved surface is determined with a linear reservoir.

$$q_{o,t} = q_{o,t-1} e^{-\frac{\Delta t}{k_r}} + P_{N,t} (1 - e^{-\frac{\Delta t}{k_r}}) \quad (17-a)$$

$$Q_{o,t} = a \Lambda_{o,t} q_{o,t} \quad (17-b)$$

Input	$q_{o,t-1}$	[mm/day]	specific discharge other open paved surface (formula 17)
model parameters	$P_{N,t}$	[mm/day]	surface runoff from open paved surface (formula 17)
	$I_{k,t}$	[mm/day]	infiltration intensity (formula 15)
	$\Lambda_{o,t}$	[ha]	other open paved surface
	k_r	[day]	time constant reservoir other open paved surface
	Δt	[day]	time step
	a	[-]	factor
output	$Q_{o,t}$	[m ³ /s]	discharge from other open paved surface

The value $q_{o,t}$ at time $t=0$ is set to zero
Paved surface which discharge is connected to open water
The factor equals 10/(24*3600)

other closed paved surface

The discharge from other closed paved surface is calculated with a single linear reservoir. The reaction time is relatively short.

$$q_{o,z,t} = q_{o,z,t-1} e^{-\Delta t/k_{o,z}} + P_{N,z,t} (1 - e^{-\Delta t/k_{o,z}}) \quad (18-a)$$

$$Q_{o,z,t} = a (A_{o,z} q_{o,z,t}) \quad (18-b)$$

input	$q_{o,z,t-1}$	[mm/day]	specific discharge other closed paved surface (formula 18)
	$P_{N,z,t}$	[mm/day]	surface runoff from closed paved surface
model parameters	$A_{o,z}$	[ha]	other closed paved surface
	$k_{o,z}$	[day]	time constant reservoir other closed paved surface
	Δt	[day]	time step
	a	[-]	factor
output	$Q_{o,z,t}$	[m ³ /s]	discharge other closed paved surface

The value for $q_{o,z,t}$ at time $t=0$ is set to zero
 ** Paved surface connected to open water
 *** The factor equals: $10/(24*3600)$

infiltrated water from open paved surface

The infiltrated water resulting from surface with a sewer system and other open paved surface is determined with a single linear reservoir.

$$q_{o,i,t} = q_{o,i,t-1} e^{-\Delta t/k_{o,i}} + I_{o,i} (1 - e^{-\Delta t/k_{o,i}}) \quad (19-a)$$

$$Q_{o,i,t} = a q_{o,i,t} (A_{o,i} + A_{o,o}) \quad (19-b)$$

Input	$q_{o,i,t-1}$	[mm/day]	specific discharge infiltrated water (formula 19)
	$I_{o,i}$	[mm/day]	infiltration intensity open paved surface (formula 15)
	$A_{o,i}$	[ha]	open paved surface with sewer system
	$A_{o,o}$	[ha]	other open paved surface
model parameters	k_i	[day]	time constant reservoir
	Δt	[day]	time step
	a	[-]	Factor
output	$Q_{o,i,t}$	[m ³ /s]	discharge infiltrated water from open paved surface

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 á 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:

$$S_{NH4-N, paved,t} = Q_{paved,t} \cdot C_{NH4-N, paved,t} \quad (20-a)$$

$$S_{NO3-N, paved,t} = Q_{paved,t} \cdot C_{NO3-N, paved,t} \quad (20-b)$$

$$S_{org-N, paved,t} = Q_{paved,t} \cdot C_{org-N, paved,t} \quad (20-c)$$

Input	$Q_{paved,t}$	[m ³ /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.

$$S_{P-total, paved,t} = Q_{paved,t} \cdot C_{P-total, paved,t} \quad (21)$$

Input	$Q_{paved,t}$	[m ³ /s]	Discharge paved surface (formula 19-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).

$$I_t = P_{b,t} + \frac{B_{t-1}}{\Delta t} \quad \text{if } P_{b,t} + \frac{B_{t-1}}{\Delta t} \leq I_{\max} \quad (22-a)$$

$$I_t = I_{\max} \quad \text{if } P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{\max} \quad (22-b)$$

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).

$$I_t = \Phi_{pf=0} - \Phi_{t-1} + P_{perc,max} \quad \text{if } \Phi_{t-1} + I_t - P_{perc,max} > \Phi_{pf=0} \quad (22-c)$$

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 $pl=2$ (to be determined from 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).

$$B_t = 0 \quad \text{if } P_{b,t} + \frac{B_{t-1}}{\Delta t} \leq I_{max} \quad (23-a)$$

$$B_t = (P_{b,t} - I_t) \Delta t + B_{t-1} \quad \text{if } P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \quad \text{and} \quad (23-b)$$

$$\text{if } (P_{b,t} - I_t) \Delta t + B_{t-1} \leq B_{max}$$

$$B_t = B_{max} \quad \text{if } P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \quad \text{and} \quad (23-c)$$

$$\text{if } (P_{b,t} - I_t) \Delta t + B_{t-1} > B_{max}$$

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.

$$P_{N,sur,t} = P_{b,t} + \frac{B_t}{\Delta t} - I_t - \frac{B_{\max}}{\Delta t} \text{ if: } (P_{b,t} - I_t)\Delta t + B_{t-1} > B_{\max} \quad (24-a)$$

$$P_{N,sur,t} = 0 \quad \text{if: } (P_{b,t} - I_t)\Delta t + B_{t-1} \leq B_{\max} \quad (24-b)$$

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 a 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 ($\psi_F = 2$). 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.

The relation between the moisture content and the evapotranspiration can be defined according to the following possibilities:

1. the exponent in the moisture content ratio
2. the definition of fixed points (markers) in the evapotranspiration function

In the dialogue window for unpaved area a choice appears for these two possibilities.

The following formulas take the place of formula 12 in the RAM manual.

ad 1.

The actual evaporation is defined according to:

$$E_{act} = f E_{pot} \quad \text{if } \phi_{pF=0} \geq \phi_{t-1} > \phi_{pF=2} \quad (26-a)$$

$$E_{act} = \left(\frac{\phi_{t-1} - \phi_{pF=1,2}}{\phi_{pF=2} - \phi_{pF=4,2}} \right)^x f E_{pot} \quad \text{if } \phi_{pF=2} \geq \phi_{t-1} > \phi_{pF=4,2} \quad (26-b)$$

$$E_{act} = 0 \quad \text{if } \phi_{t-1} < \phi_{pF=4,2} \quad (26-c)$$

Input	Φ_{t-1}	[mm]	Actual moisture storage(formula 28)
	$\Phi_{pf=0}$	[mm]	Moisture storage at pf=0 (formula 21)
	$\Phi_{pf=2}$	[mm]	Moisture storage at pf=2 (formula 21)
	$\Phi_{pf=4.2}$	[mm]	Moisture storage at pf=4.2 (formula 21)
Modelling parameters	f	[-]	Crop factor Makkink
	E_{ref}	[mm/day]	Reference crop evaporation Makkink
	x	[-]	Exponent
Output	E_{act}	[mm/day]	Actual evapotranspiration

If the exponent is not defined the default value equals 1.

ad 2.

The relation between the moisture content en the actual evaporation is defined through a linear interpolation of the evaporation between zero at pf=4.2 and the potential evaporation at pf=2. When fixing the relation with markers a number of i extra points have to be defined with a certain moisture supply/stock and an accompanying evaporation- reduction-factor. The reduction-factor is calculated between the user-defined markers.

$$E_{act} = f E_{ref} \quad \text{if } \Phi_{pf=0} \geq \Phi_{t-1} > \Phi_{pf=2} \quad (26-d)$$

$$E_{act} = (V_{01} + \left(\frac{\Phi_{t-1} - \Phi_j}{\Phi_{pf=2} - \Phi_j} \right) (1 - V_{01})) f E_{ref} \quad \text{if } \Phi_{pf=2} \geq \Phi_{t-1} > \Phi_j \quad (26-e)$$

For the 2nd t/m ith number applies:

$$E_{act} = (V_{0i} + \left(\frac{\Phi_{t-1} - \Phi_i}{\Phi_{t-1} - \Phi_i} \right) (V_{0i-1} - V_{0i})) f E_{ref} \quad \text{if } \Phi_{t-1} \geq \Phi_{t-1} > \Phi_i \quad (26-f)$$

$$E_{act} = \left(\frac{\Phi_{t-1} - \Phi_{pf=4.2}}{\Phi_i - \Phi_{pf=4.2}} \right) V_{0i} f E_{ref} \quad \text{if } \Phi_i \geq \Phi_{t-1} > \Phi_{pf=4.2} \quad (26-g)$$

$$E_{act} = 0 \quad \text{if } \Phi_{t-1} < \Phi_{pf=4.2} \quad (26-h)$$

Input	$\Phi_{i,t}$	[mm]	Actual moisture storage (formula 29)
	$\Phi_{pF=0,t}$	[mm]	Moisture storage at pF=0 (formula 26)
	$\Phi_{pF=2,t}$	[mm]	Moisture storage at pF=2 (formula 26)
	$\Phi_{pF=4.2,t}$	[mm]	Moisture storage pF=4.2 (formula 26)
	$\Phi_{i,t}$	[mm]	Moisture storage for marker i (formula 26)
Modelling parameters	$E_{i,t}$	mm/day]	reference crop evaporation Makkink
	v_{Φ_i}	[-]	Evaporation-reduction-factor at Φ_i
	Θ_i	[-]	Moisture content for marker i
	f	[-]	Crop factor Makkink
	i	[-]	Number of markers
Output	$E_{a,t}$	[mm/day]	Actual evapotranspiration

$$* \quad \Phi_i < \Phi_{i-1}$$

$$** \quad 0 \leq v \leq 1 \text{ en } v_{\Phi_i} \leq v_{\Phi_{i-1}}$$

No extra markers will be defined if i is not filled in.

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.

The percolation relation can be made flexible in the same manner as the evapotranspiration function.

ad 1.

If an exponent for the moisture storage ratio is used is defined the percolation is established in the following manner:

$$P_{percol,t} = \left(\frac{\Phi_{t,t} - \Phi_{pF=2}}{\Phi_{pF=0} - \Phi_{pF=2}} \right)^n P_{percol,max} \quad \text{if } \Phi_{pF=0} \geq \Phi_{t,t} > \Phi_{pF=2} \quad (27-a)$$

$$P_{percol,t} = 0 \quad \text{if } \Phi_{t,t} \leq \Phi_{pF=2} \quad (27-b)$$

Input	$\Phi_{i,t}$	[mm]	Actual moisture storage (formula 53)
	$\Phi_{i,t=0}$	[mm]	Moisture storage at pf=0 (formula 56)
	$\Phi_{i,t=2}$	[mm]	moisture storage at pf=2 (formula 56)
	$\Phi_{i,t=4.2}$	[mm]	Moisture storage at pf=4.2 (formula 56)
Modelling parameters	$P_{per,max}$	[mm/day]	Maximum percolation rate to saturated zone
	γ	[-]	Exponent
Output	$P_{per,t}$	[mm/day]	Percolation rate to saturated zone

If the exponent is not defined the default value equals 1.

ad 2.

The relation between soil moisture storage and percolation rate is established through a linear interpolation of the percolation rate between zero at pf=2 and the maximum percolation rate at pf=0. When establishing the relation between the moisture storage and the percolation rate through the use of markers, the soil moisture storage and the accompanying percolation-reduction-factor are used. With the following formula the percolation rate is established:

$$P_{per,t} = (p_{oi} + (\frac{\Phi_{i,t} - \Phi_i}{\Phi_{i,t=0} - \Phi_i})(1 - p_{oi})) P_{per,max}$$

if $\Phi_{i,t} \geq \Phi_{i=2} > \Phi_i$ (27-d)

For m is the 2nd /mth marker applies:

$$P_{per,t} = (p_{oi} + (\frac{\Phi_{i,t} - \Phi_i}{\Phi_{i,t=0} - \Phi_i})(p_{oi} - p_{oi})) P_{per,max}$$

if $\Phi_{i,t} \geq \Phi_{i=0} > 0$ (27-e)

$$P_{per,t} = (\frac{\Phi_{i,t} - \Phi_{i=2}}{\Phi_i - \Phi_{i=2}}) p_{oi} P_{per,max}$$

if $\Phi_i \geq \Phi_{i,t} > \Phi_{i=2}$ (27-f)

$$P_{per,t} = 0$$

if $\Phi_{i,t} \leq \Phi_{i=2}$ (27-g)

Input	$\Phi_{i,t}$	[mm]	Actual moisture storage (formula 53)
	$\Phi_{i,t=0}$	[mm]	Moisture storage at pf=0 (formula 56)
	$\Phi_{i,t=2}$	[mm]	moisture storage at pf=2 (formula 56)
	Φ_i	[mm]	Moisture storage for marker i (formula 56)
Modelling parameters	$P_{per,max}$	[mm/day]	Maximum percolation rate
	p_{oi}	[-]	Percolation-reduction-factor at moisture content i
	Θ_i	[-]	Moisture content at marker i
Output	i	[-]	Number of markers
	$P_{per,t}$	[mm/day]	Percolation rate

$$\Phi_i < \Phi_i$$

$$** \quad 0 \leq p \leq 1 \text{ en } p_{\Phi_i} \leq p_{\Phi_{i-1}}$$

No extra markers will be defined if i is not filled in.

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)

$$\Phi_t = \Phi_{t-1} + (I_t - E_{a,t} - P_{perc,t}) \Delta t \quad (28)$$

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 $p_f=2$ (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 ($p_f=2$) and at the wilting point ($p_f=4.2$) 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:

$$- \quad \Phi_{pF=0} = 0.371 \times 0.8\text{m} = 296.8\text{mm}$$

$$- \quad \Phi_{pF=2} = 0.201 \times 0.8\text{m} = 160.8\text{mm}$$

$$- \quad \Phi_{pF=4.2} = 0.003 \times 0.8\text{m} = 24\text{mm}$$

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).

$$q_{sur,t} = q_{sur,t-1} e^{-k_{sur}} + P_{N,sur,t} (1 - e^{-k_{sur}}) \quad (29-a)$$

$$Q_{sur,t} = a A_{unpaved} q_{sur,t} \quad (29-b)$$

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)
	$\Lambda_{unpaved}$	[ha]	Unpaved surface
Model Parameters	k_{sur}	[day]	Time constant reservoir surface runoff unpaved surface
	Δt	[day]	Time step
	a^{**}	[-]	Conversion factor units
Output	$P_{sur,t}$	[m ³ /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 1st reservoir:

$$q_{quick,i,t} = q_{quick,i,t-1} e^{-\frac{\Delta t}{k^q}} + (1-\beta)P_{perc,t} (1 - e^{-\frac{\Delta t}{k^q}}) \quad (30-a)$$

For i is the 2nd unto and including the m^{th} reservoir:

$$q_{quick,i,t} = q_{quick,i,t-1} e^{-\frac{\Delta t}{k_q}} + q_{quick,i-1,t} (1 - e^{-\frac{\Delta t}{k_q}}) \quad (30-b)$$

For the 1st reservoir:

$$q_{slow,1,t} = q_{slow,1,t-1} e^{-\frac{\Delta t}{k_s}} + \beta P_{perc,t} (1 - e^{-\frac{\Delta t}{k_s}}) \quad (30-c)$$

For i is the 2nd upto and including the n^{th} reservoir:

$$q_{slow,i,t} = q_{slow,i,t-1} e^{-\frac{\Delta t}{k_s}} + q_{slow,i-1,t} (1 - e^{-\frac{\Delta t}{k_s}}) \quad (30-d)$$

$$Q_{quick,t} = a A_{unpaved} q_{quick,m,t} \quad (30-e)$$

$$Q_{slow,t} = a A_{unpaved} q_{slow,n,t} \quad (30-f)$$

Input	$P_{perc,t}$ $q_{slow,i,t-1}$ $q_{quick,i,t-1}$ $A_{unpaved}$	[mm/day] [mm/day] [mm/day] [ha]	Percolation into the saturated zone (formula 28) Specific slow component ground water discharge unpaved surface (formula 30) Specific quick component ground water discharge unpaved surface (formula 30) Unpaved surface
Model Parameters	β k_s k_q m n Δt a	[-] [day] [day] [-] [-] [day] [-]	Distribution code quick and slow components ground water discharge Time constant reservoir slow component ground water discharge Time constant reservoir quick component ground water discharge Number of reservoirs quick component ground water discharge Number of reservoirs slow component ground water discharge Time step Conversion factor units
Output	$Q_{slow,t}$ $Q_{quick,t}$	[m ³ /s] [m ³ /s]	Drainage slow component ground water discharge 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 $10/24 \times 3600$

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 d^{th} reservoir:

$$q_{quick,i,t} = (1 - \beta) * \left\{ \frac{1}{(2d-1) \sum_{j=1,3,5...}^d j^2} p_{perc,t} \frac{1}{(2i-1)^2} (1 - e^{-\frac{-\Delta t (2i-1)^2}{k_q}}) \right\} + q_{quick,i,t-1} e^{-\frac{-\Delta t (2i-1)^2}{k_q}}$$

(31-a)

For the 1st reservoir:

$$q_{slow,1,t} = q_{slow,1,t-1} e^{-\frac{-\Delta t}{k_s}} + \beta p_{perc,t} (1 - e^{-\frac{-\Delta t}{k_s}})$$

(31-b)

For i is the 2nd upto and including the n^{th} reservoir:

$$q_{slow,i,t} = q_{slow,i,t-1} e^{-\frac{-\Delta t}{k_s}} + q_{slow,i-1,t} (1 - e^{-\frac{-\Delta t}{k_s}})$$

(31-c)

$$Q_{quick,t} = a A_{unpaved} \left(\sum_{i=1}^d q_{quick,i,t} \right)$$

(31-d)

$$Q_{slow,t} = a A_{unpaved} q_{slow,n,t}$$

(31-e)

Input	$p_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 28)
	$q_{slow,i,t-1}$ *	[mm/day]	Specific slow component ground water discharge unpaved surface (formula 31)
	$q_{quick,i,t-1}$ *	[mm/day]	Specific quick component ground water discharge unpaved surface (formula 31)
	$A_{unpaved}$	[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
	$\frac{\Delta t}{a^{***}}$	[day]	Time step
Output	$Q_{slow,t}$	[m ³ /s]	Discharge slow component ground water discharge
	$Q_{quick,t}$	[m ³ /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 discretised 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 discretised 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 Interaction between the saturated and unsaturated zone

The change in length of the linear reservoirs (which is an indication for the change in the groundwater head) has to be subtracted from the length of the soil moisture reservoir. This has an impact on the trajectory between the different pressure heads and the boundary conditions for evapotranspiration and percolation. The soil moisture storage balance is not subject to change. It is possible to describe the capillary rise in the percolation term.

The change in the storage in the saturated zone has an impact on the depth of the unsaturated zone and also on the characteristics of the soil moisture reservoir (the moisture content at different pressure heads). Directly after calculation of the actual moisture content the moisture content is calculated.

$$\theta_t = \frac{\phi_t}{L_{bv,t}} \quad (32)$$

input	Φ_t	[mm]	moisture storage
	$L_{bv,t}$	[mm]	depth of unsaturated zone
output	Θ_t	[-]	moisture content

The depth of the unsaturated zone is established through the depth at the preceding timestep minus the change in depth of the saturated zone as described in the following formula:

$$\Delta L_{bv} = L_{bv,t-1} - (P_{perc,t} - q_{snel,t} - q_{langzaam,t}) \Delta t \cdot \frac{\theta_{t-1}}{N} \quad (33)$$

Input	$L_{bv,t-1}$	[mm]	Depth of unsaturated zone (formula 33)
	$P_{perc,t}$	[mm/day]	Percolation rate (formula 31)
	$q_{quick/snel,t}$	[mm/day]	Specific quick component of groundwater discharge
	$q_{slow/langzaam,t}$	[mm/day]	Specific slow component of groundwater discharge
	Θ_t	[-]	Soil moisture content (formula 35)
Modelling parameters	$L_{bv,0}$	[mm]	Initial depth of unsaturated zone
	N	[-]	Pore content
	Δt	[day]	Time step
Output	$L_{bv,t}$	[mm]	Depth of unsaturated zone

$$\phi_t = \phi_{t-1} \cdot \frac{L_{bv,t}}{L_{bv,t-1}} \quad (55)$$

Input	Φ_t	[-]	Soil moisture storage (formula 35)
	$L_{bv,t}$	[mm]	Depth of unsaturated zone (formula 34)
Output	Φ_t	[mm]	Soil moisture storage

When establishing a new depth of the unsaturated zone the characteristics of the unsaturated zone, the soil moisture storage at pF=0, pF=2, pF=4,2 and user defined markers change in the following manner:

$$\phi_{i,t} = \phi_{i,t-1} \cdot \frac{I_{i,t-1}}{I_{i,t-1,t}} \quad (34)$$

Input	$I_{i,t-1}$	[mm]	Depth of unsaturated zone (formula 34)
Output	$\phi_{i,t}$	[mm]	Soil moisture storage at pressure head i

capillary rise

We suggest to take into account a capillary rise as a function of the filling of the soil moisture reservoir and the filling of the linear reservoir.

Therefore the maximum flux (capillary rise) has to be given and also a filling value of the linear reservoir at which the capillary rise is activated. In a dialogue window the choice can be made if the capillary rise is used and in which months (depending on growing season).

The following formulas, which are added to the percolation function are used:

$$P_{per,t} = \frac{\phi_{i,t-1} - \phi_{pf=2,t-1} - C_{max}}{\phi_{pf=4.2,t-1} - \phi_{pf=2,t-1}} \cdot C_{max} \quad \text{if } \phi_{pf=2,t-1} \geq \phi_{i,t-1} > \phi_{pf=4.2,t-1} \quad (35-a)$$

$$\text{and } BL \geq BL_{max}$$

$$P_{per,t} = C_{max} \quad \text{if } \phi_{i,t-1} \leq \phi_{pf=4.2,t-1} \quad (35-b)$$

$$\text{and } BL \geq BL_{min}$$

$$\text{see formula 31} \quad \text{if } \phi_{i,t-1} \geq \phi_{pf=2,t-1}$$

$$\text{and if } BL \leq BL_{min}$$

Input	$\Phi_{i,t}$	[mm/day]	Actual moisture storage (formula 56)
	BL_t	[mm]	Actual storage in linear reservoirs (formula 58)
	$\Phi_{pf=2,t}$	[mm]	Moisture storage at pF=2 (formula 56)
	$\Phi_{pf=4.2,t}$	[mm]	Moisture storage at pF=4.2 (formula 56)
Modelling parameters	BL_{max}	[mm]	Storage value in linear reservoirs at which capillary rise is activated
Output	C_{max}	[mm/day]	Maximum capillary rise
	$P_{per,t}$	[mm/day]	Capillary rise (as percolation term)

The storage in the linear reservoir is calculated with the following balance:

$$BL_t = BL_{t-1} + \frac{P_{per,t} - q_{out,t} - q_{trans,down,t}}{\Delta t} \quad (36)$$

Input	BL_{t-1}	[mm]	Actual storage in linear reservoirs (formula 58)
	$P_{perc,t}$	[mm/day]	Percolation rate (formula 52)
	$P_{perc,t}$	[mm/day]	Capillary flux as percolation term (formula 57)
	$q_{quick/snel,t}$	[mm/day]	Specific quick component of groundwater discharge
	$q_{slow/langzaam,t}$	[mm/day]	Specific slow component of groundwater discharge
Output	BL_t	[mm]	Storage in linear reservoir

4.4.5 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).

4.4.5.1 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.

$$S_{NH4-N, sur, t} = Q_{sur, t} * C_{NH4-N, sur, t} \quad (37-a)$$

$$S_{NO3-N, sur, t} = Q_{sur, t} * C_{NO3-N, sur, t} \quad (37-b)$$

$$S_{org-N, sur, t} = Q_{sur, t} * C_{org-N, sur, t} \quad (37-c)$$

Input	$Q_{sur, t}$	[m ³ /s]	Surface runoff unpaved surface (formula 15-b)
Model Parameters	$C_{NH4-N, sur, t}$	[mgN/l]	Ammonium-N concentration surface runoff unpaved surface
	$C_{NO3-n, sur, t}$	[mg N/l]	Nitrate concentration surface runoff unpaved surface
	$C_{org-N, sur, t}$	[mg N/l]	Organic nitrogen concentration surface runoff unpaved surface
Output	$S_{NH4-N, sur, t}$	[g N/s]	Ammonium load surface runoff unpaved surface
	$S_{NO3-N, sur, t}$	[g N/s]	Nitrate load surface runoff unpaved surface
	$S_{org-N, sur, t}$	[g N/s]	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.

$$S_{P-total, sur, t} = Q_{opp, t} * C_{P-total, sur, t} \quad (38)$$

Input	$Q_{sur,t}$	[m ³ /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 from the literature are listed in table 7.

4.4.5.2 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 top layer 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.

$$S_{NH4-N,quick,t} = Q_{quick,t} * C_{NH4-N,quick,t} \quad (39-a)$$

$$S_{NO3-N,quick,t} = Q_{quick,t} * C_{NO3-N,slow,t} / N \quad (39-b)$$

Input	$Q_{quick,t}$	[m ³ /s]	Quick component ground water discharge unpaved surface (formula 35 or 36)
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.

$$S_{P-total,quick,t} = Q_{quick,t} \cdot C_{P-total,quick,t} \quad (40)$$

Input	$Q_{quick,t}$	[m ³ /s]	Quick component ground water discharge unpaved surface (formula 35 or 36)
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 regard 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			0,1-3,2c		0,1-3,2c
clay							1-3a					
peat							2a					
quick component of the ground water discharge												
sand	2d			4b					3b			2b
clay	1d											
peat	2d											
slow component of the ground water discharge												
sand	1,5d 0,03-4,3e 21-39a	0,08-0,36e	<0,01e	21-39a 43d				21-39a 80c 113d			21-39a 20d	
clay	0,07-0,7e	3,4-13,1e	1,4-6c	53d							14d	
peat	0,2-0,8e	0,9-3,6c	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

4.4.5.3 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 nitrified into nitrate by bacteria in aerobic circumstances. This is denitrified into N₂ 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 denitrifying 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.

$$S_{NH4-N,slow,t} = Q_{slow,t} \cdot C_{NH4-N,slow,t} \quad (41-a)$$

$$S_{NO3-N,slow,t} = Q_{slow,t} \cdot C_{NO3-N,slow,t} \quad (41-b)$$

Input	$Q_{slow,t}$	[m ³ /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.

$$S_{P-total,slow,t} = Q_{slow,t} \cdot C_{P-total,slow,t} \quad (42)$$

Input	$Q_{slow,t}$	[m ³ /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.

4.4.5.4 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 an 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 subflows 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.

$$q_{seep,t} = \frac{\Delta h}{c} \quad (43-a)$$

$$Q_{seep,t} = b A_{total} q_{seep,t} \quad (43-b)$$

Input	Δh	[m]	Hydraulic head difference
	c	[day]	Vertical hydraulic resistance
	A_{total}	[ha]	Total surface
Model Parameters	b	[-]	Conversion factor units
Output	$Q_{seep,t}$	[m ³ /s]	Discharge seepage

* The conversion factor is equal to 10000/(24*3600).

The related water quality is determined by a zero order equation.

$$S_{NH4-N,seep,t} = Q_{seep,t} * C_{NH4-N,seep,t} \quad (44-a)$$

$$S_{NO3-N,seep,t} = Q_{seep,t} * C_{NO3-N,seep,t} \quad (44-b)$$

Input	$Q_{seep,t}$	[m ³ /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

$$S_{P-total,seep,t} = Q_{seep,t} * C_{P-total,seep,t} \quad (45)$$

Input	$Q_{seep,t}^P$	[m ³ /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

$$Q_{unpaved,t} = Q_{sur,t} + Q_{quick,t} + Q_{slow,t} \quad (46-a)$$

$$Q_{total,t} = Q_{open\ water,t} + Q_{paved,t} + Q_{unpaved,t} + Q_{seep,t} \quad (46-b)$$

Input	$Q_{open\ water,t}$	[m ³ /s]	Discharge open water surface (formula 2-b)
	$Q_{unpaved,t}$	[m ³ /s]	Discharge unpaved surface (formula 27-a)
	$Q_{paved,t}$	[m ³ /s]	Discharge paved surface (formula 6-c)
	$Q_{sur,t}$	[m ³ /s]	Surface discharge unpaved surface (formula 15-b)
	$Q_{quick,t}$	[m ³ /s]	Quick component of ground water discharge unpaved surface (formula 16 or 17)
	$Q_{slow,t}$	[m ³ /s]	Slow component of ground water discharge unpaved surface (formula 16 or 17)
	$Q_{seep,t}$	[m ³ /s]	Runoff seepage (formula 24)
Model Parameters	-	-	-
Output	$Q_{total,t}$	[m ³ /s]	Total discharge

The total of nitrate and ammonium loads in a catchment area is determined in accordance with:

$$S_{NH4-N,unpaved,t} = S_{NH4-N,sur,t} + S_{NH4-N,quick,t} + S_{NH4-N,slow,t} + S_{NH4-N,seep,t} \quad (28-a)$$

$$S_{NO3-N,unpaved,t} = S_{NO3-N,sur,t} + S_{NO3-N,quick,t} + S_{NO3-N,slow,t} + S_{NO3-N,seep,t} \quad (28-h)$$

$$S_{NH4-N,total,t} = S_{NH4-N,open\ water,t} + S_{NH4-N,paved,t} + S_{NH4-N,unpaved,t} \quad (28-c)$$

$$S_{NO3-N,total,t} = S_{NO3-N,open\ water,t} + S_{NO3-N,paved,t} + S_{NO3-N,unpaved,t} \quad (28-d)$$

$$S_{org-N,total,t} = S_{org-N,paved,t} + S_{org-N,sur,t} \quad (28-e)$$

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:

$$S_{P-total,unpaved,t} = S_{P-total,sur,t} + S_{P-total,quick,t} + S_{P-total,slow,t} + S_{P-total,seep,t} \quad (29-A)$$

$$S_{P-total,total,t} = S_{P-total,open\ water,t} + S_{P-total,paved,t} + S_{P-total,unpaved,t} \quad (29-B)$$

Input	$S_{P-total,open\ water,t}$	[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 hydrograph. 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.

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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 Makkin (Cultuurtechnisch Vademecum, 1988)

month decade	April			May			June			July			August			September		
	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 onions	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 onions	-	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	1.8	1.8	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				
<i>Zand</i>				
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
<i>Zavel</i>				
B7 zeer lichte zavel		8 - 12	0 - 15	
B8 matig lichte zavel		12 - 18	0 - 15	
B9* zware zavel		18 - 25	0 - 15	
<i>Klei</i>				
B10 lichte klei		25 - 35	0 - 15	
B11 matig zware klei		35 - 50	0 - 15	
B12 zeer zware klei		50 - 100	0 - 15	
<i>Leem</i>				
B13* zandige leem	50 - 85		0 - 15	
B14* siltige leem	85 - 100		0 - 15	
<i>Moerig</i>				
B15* venig zand		0 - 8	15 - 25	
B16 zandig veen en veen		0 - 8	23 - 100	
B17* venige klei		8 - 100	16 - 45	
B18 kleig veen		8 - 100	25 - 70	
ONDERGRONDEN				
<i>Zand</i>				
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* heekleem	33 - 50			
<i>Zavel</i>				
O8 zeer licht zavel		8 - 12	0 - 3	
O9 matig lichte zavel		12 - 18	0 - 3	
O10 zware zavel		18 - 25	0 - 3	
<i>Klei</i>				
O11 lichte klei		25 - 35	0 - 3	
O12 matig zware klei		35 - 50	0 - 3	
O13 zeer zware klei		50 - 100	0 - 3	
<i>Leem</i>				
O14* zandige leem	50 - 85		0 - 3	
O15 siltige leem	85 - 100		0 - 3	
<i>Veen</i>				
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 (Wosten *et al.*, 1987).

	θ (%) bij 13 waarden voor $ h $, resp. pF														θ_{hw} bij pF		
	1	10	20	31	50	100	250	500	1000	2500	5000	10000	16000	1,7	2,0	2,3	
$ h $ (cm)	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	-	-	-	
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	
HOVENGRONDEN																	
B1	37,1	36,4	35,7	34,7	28,0	20,1	13,0	9,8	7,4	5,4	4,3	3,4	3,0	25,0	17,1	11,5	
B2	43,2	40,1	39,2	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	41,7	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	11,1	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	24,6	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	53,1	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	22,1	17,6	14,5	12,9	49,8	46,0	40,1	
B18	71,7	69,8	68,5	67,1	65,2	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	11,1	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	29,2	23,2	14,2	9,2	6,2	4,4	3,4	2,8	2,5	26,7	20,7	13,8	
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	14,1	11,8	10,4	29,6	27,7	24,3	
O11	41,9	40,0	39,3	38,7	38,1	36,5	33,1	29,6	26,2	22,1	19,2	16,6	15,0	23,1	21,5	19,7	
O12	49,2	47,8	47,3	47,0	46,4	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	52,2	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	38,8	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

hydrologische kringloop

afvoer

afvoerbare neerslag

afwateringsstelsel

bergingscapaciteit van de onverzadigde zone

capillaire opstijging

capillaire zoom

depressieberging

drain

drainage-afvoer

evaporatie

evapotranspiratie

grondafvoer

grondwaterstand

grondwaterstandsdiepte

hydrologische kringloop

infiltratie

infiltratiecapaciteit

interceptie

kwel

neerslag

neerslagintensiteit

neerslagoverschot

netto neerslag

onverzadigde zone

ontwatering

oppervlakte-afvoer

percolatie

schijnspiegel

schijnspiegelafvoer

English

hydrological cycle

discharge

effective precipitation

drainage system

storage capacity of the unsaturated zone

Upward capillary migration /capillary rise

capillary fringe

Storage in surface depressions

drain pipe

drainage

evaporation

evapotranspiration

ground water discharge

ground water level

depth of the groundwater level

hydrologic cycle

infiltration

infiltration capacity

interception

seepage / exfiltration

precipitation

precipitation intensity

precipitation

precipitation excess

unsaturated zone

drainage

surface runoff

percolation

perched water table / apparent water table

interflow

specifieke afvoer	specific discharge
stroomgebied	catchment area
transpiratie	transpiration
veldecapaciteit	field capacity
verwelkingspunt	wilting point
verzadigde zone	zone of saturation
waterbalans	water balance
wegzijging	downward seepage
wortelzone	root zone

waterkwaliteit

adsorptie
afspoeling
denitrificatie
desorptie
droge depositie
fosforbindend vermogen (FVB)
immobilisatie
mineralisatie
natte depositie
nitrificatie
omzettingsprocessen
uitspoeling
vervluchting

water quality

adsorption
runoff
denitrification
desorption
dry deposition
phosphorus fixation capacity
fixation / immobilization
mineralization
wet deposition
nitrification
reaction processes
leaching
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 watercourse.
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	Instantaneous 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.

Terms in nitrogen and phosphor balances

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 nitrifying 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.

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_o	[day]	Time constant reservoir open water surface
k_l	[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
$Q_{\text{open water}}$	[m ³ /s]	Discharge open water surface
Q_{paved}	[m ³ /s]	Discharge paved surface
Q_{quick}	[m ³ /s]	Quick ground water drainage unpaved surface
Q_{seep}	[m ³ /s]	Seepage
Q_{slow}	[m ³ /s]	Slow ground water drainage unpaved surface
Q_{sur}	[m ³ /s]	Surface drainage unpaved surface
Q_{unpaved}	[m ³ /s]	Discharge unpaved surface
Q_{total}	[m ³ /s]	Total drainage
β	[-]	Distribution key for quick and slow ground water drainage
Δt	[day]	Time step
Φ	[mm]	Actual moisture storage
$\Phi_{\text{pF} = 0}$	[mm]	Moisture storage at pF = 0 (saturated)
$\Phi_{\text{pF} = 2}$	[mm]	Moisture storage at pF = 2 (field capacity)
$\Phi_{\text{pF} = 4.2}$	[mm]	Moisture storage at pF = 4.2 (wilting point)
Δh	[m]	Hydraulic head difference
c	[day]	Vertical hydraulic resistance
$C_{\text{NH}_4\text{-N, paved}}$	[mg N/l]	Ammonium-N concentration paved surface
$C_{\text{NH}_4\text{-N, precipitation}}$	[mg N/l]	Ammonium-N concentration precipitation
$C_{\text{NH}_4\text{-N, seepage}}$	[mg N/l]	Ammonium-N concentration seepage
$C_{\text{NH}_4\text{-N, slow}}$	[mg N/l]	Ammonium-N concentration slow ground water runoff unpaved surface
$C_{\text{NH}_4\text{-N, sur}}$	[mg N/l]	Ammonium-N concentration surface runoff unpaved surface
$C_{\text{NH}_4\text{-N, quick}}$	[mg N/l]	Ammonium-N concentration quick ground water runoff unpaved surface
$C_{\text{NH}_4\text{-N, unpaved}}$	[mg N/l]	Ammonium-N concentration unpaved surface
$C_{\text{NO}_3\text{-N, paved}}$	[mg N/l]	Nitrate-N concentration paved surface
$C_{\text{NO}_3\text{-N, precipitation}}$	[mg N/l]	Nitrate-N concentration precipitation
$C_{\text{NO}_3\text{-N, seepage}}$	[mg N/l]	Nitrate-N concentration seepage
$C_{\text{NO}_3\text{-N, slow}}$	[mg N/l]	Nitrate-N concentration slow ground water runoff unpaved surface
$C_{\text{NO}_3\text{-N, sur}}$	[mg N/l]	Nitrate-N concentration surface runoff unpaved surface
$C_{\text{NO}_3\text{-N, quick}}$	[mg N/l]	Nitrate-N concentration quick ground water runoff unpaved surface
$C_{\text{NO}_3\text{-N, unpaved}}$	[mg N/l]	Nitrate-N concentration unpaved surface
$C_{\text{org N, paved}}$	[mg N/l]	Organically fixed nitrogen concentration paved surface
$C_{\text{org N, sur}}$	[mg N/l]	Organically fixed nitrogen concentration surface drainage unpaved surface
$C_{\text{P, total, paved}}$	[mg P/l]	Phosphor concentration paved surface
$C_{\text{P, total, precipitation}}$	[mg P/l]	Phosphor concentration precipitation
$C_{\text{P, total, quick}}$	[mg P/l]	Phosphor concentration quick ground water runoff unpaved surface
$C_{\text{P, total, seepage}}$	[mg P/l]	Phosphor concentration seepage
$C_{\text{P, total, slow}}$	[mg P/l]	Phosphor concentration slow ground water runoff unpaved surface
$C_{\text{P, total, sur}}$	[mg P/l]	Phosphor concentration surface runoff unpaved surface
$C_{\text{P, total, unpaved}}$	[mg P/l]	Phosphor concentration unpaved surface
$S_{\text{NH}_4\text{-N, open water}}$	[kg N/s]	Ammonium-N load open water surface
$S_{\text{NH}_4\text{-N, paved}}$	[kg N/s]	Ammonium-N load paved surface
$S_{\text{NH}_4\text{-N, quick}}$	[kg N/s]	Ammonium-N load quick ground water runoff unpaved surface

$S_{NH4-N, seepage}$	[kg N/s]	Ammonium-N load seepage/percolation
$S_{NH4-N, slow}$	[kg N/s]	Ammonium-N load slow ground water runoff unpaved surface
$S_{NH4-N, sur}$	[kg N/s]	Ammonium-N load surface runoff unpaved surface
$S_{NH4-N, total}$	[kg N/s]	Total ammonium-N load
$S_{NH4-N, unpaved}$	[kg N/s]	Ammonium-N load unpaved surface
$S_{NO3-N, open\ water}$	[kg N/s]	Nitrate load open water surface
$S_{NO3-N, paved}$	[kg N/s]	Nitrate load paved surface
$S_{NO3-N, seepage}$	[kg N/s]	Nitrate load seepage/percolation
$S_{NO3-N, quick}$	[kg N/s]	Nitrate load quick ground water runoff unpaved surface
$S_{NO3-N, slow}$	[kg N/s]	Nitrate load slow ground water runoff unpaved surface
$S_{NO3-N, sur}$	[kg N/s]	Nitrate load surface runoff unpaved surface
$S_{NO3-N, total}$	[kg N/s]	Total nitrate load
$S_{NO3-N, unpaved}$	[kg N/s]	Nitrate load unpaved surface
$S_{org-N, paved}$	[kg N/s]	Organically fixed nitrogen concentration paved surface
$S_{org-N, sur}$	[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
$S_{P-total-N, seepage}$	[kg P/s]	Phosphor load quick ground water runoff unpaved surface
$S_{P-total-N, slow}$	[kg P/s]	Phosphor load slow ground water runoff unpaved surface
$S_{P-total-N, sur}$	[kg P/s]	Phosphor load surface runoff unpaved surface
$S_{P-total-N, total}$	[kg P/s]	Total phosphor load
$S_{P-total-N, unpaved}$	[kg P/s]	Phosphor load unpaved surface