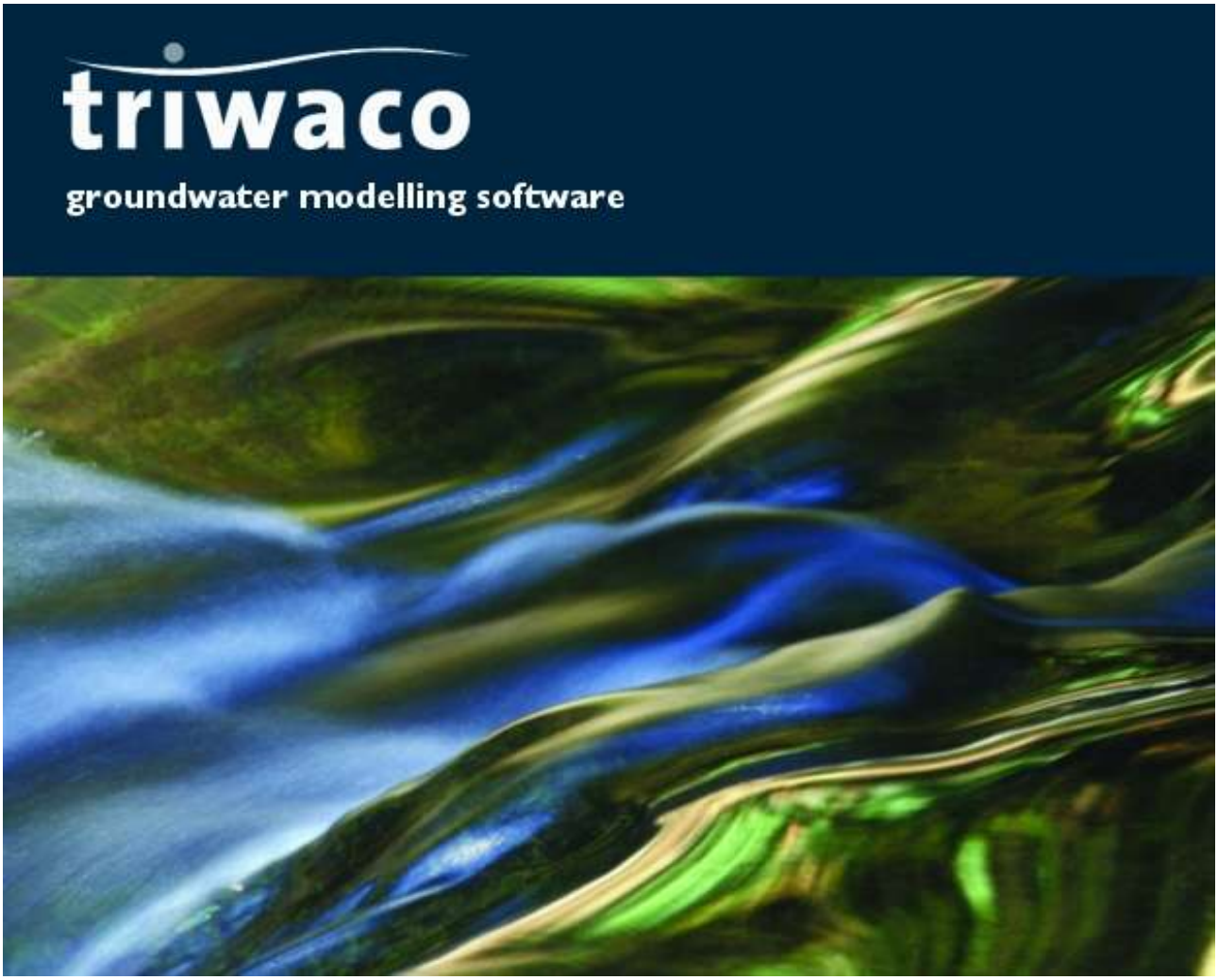


A Topsystems

ROYAL HASKONING

Appendix A: Topsystems

A.1 Introduction

The discharge or recharge of groundwater at the top of the first aquifer can be characterized by the so-called ***top-systems***. A top-system describes the interaction between the groundwater system and a drainage system consisting of generally small surface waters and drains.

Currently nine different types of top-systems are available in **Triwaco**, of which one with two sub-types. Each top-system has its own set of recharge parameters, varying form only one to up to thirteen. Specifying the top-system number (**IR**) within **Triwaco** causes the program to load the corresponding number of parameters.

Topsystem 1: Precipitation; Defined by 1 parameter; groundwater recharge is equal to the precipitation excess.

Topsystem 2: Polder with fixed water level; Defined by 3 parameters; groundwater recharge and discharge depend on a fixed water level and the (total) resistance of the drainage system.

Topsystem 3: Phreatic drainage; Defined by 3 parameters; groundwater discharge depends on the head in the top aquifer, the resistance and the base of the drainage system.

Topsystem 4: Three-level drainage/infiltration system; Defined by 13 parameters; groundwater recharge or discharge depends on the precipitation excess and the resistance and levels of a primary, secondary and tertiary drainage system.

Topsystem 5/6: Pipe drainage and irrigation or precipitation; Top-system number 5 (drainage only) and Top-system number 6 (both drainage and infiltration), defined by 8 parameters; groundwater discharge depends on the precipitation or irrigation excess, the head in the top aquifer and the drainage resistance.

Topsystem 7: Polder with a fixed water level and precipitation; Defined by 4 parameters; groundwater recharge or discharge depends on a fixed water level, the (total) resistance of the drainage system and the precipitation excess.

Topsystem 10: Phreatic drainage with precipitation; Defined by 4 parameters; groundwater discharge depends on the head in the top aquifer, the resistance and the base of the drainage system and on the precipitation excess.

Topsystem 11: Polder with a fixed water level and single drainage system; Defined by 5 parameters; groundwater recharge or discharge depends on the precipitation excess and the resistance and level of a single drainage system.

Topsystem 12: Predefined recharge or discharge characteristic; Defined by 5 parameters; groundwater recharge or discharge depends on meteorological quantities and soil parameters. The soil parameters are obtained by curve fitting of the Van Genuchten relations.

Important note Recharge, the flux that enters the groundwater system, is considered positive. Hence the discharge towards the drainage system, or due to seepage, has negative values. Thus, the parameter QRCH that result from the groundwater flow calculations has the opposite sign from the fluxes passing the confining layers, QKW1 to QKW***x***.

A.2 Overview of topsystem parameters in relation to different topsystems

IR	RP1	RP2	RP3	RP4	RP5	RP6	RP7	RP8	RP9	RP10	RP11	RP12	RP13
1	P												
2	H_P	C_0	W										
3	H_S	W	BD										
4	P	C_0	H_P	$W_{d,1}$	$W_{d,2}$	$W_{d,3}$	$W_{i,1}$	$W_{i,2}$	$W_{i,3}$	BD_1	BD_2	BD_3	H_S
5	P	H_S	H_d	H_T	K_v	K_h	L	R					
6	P	H_S	H_d	H_T	K_v	K_h	L	R					
7	P	C_0	W	H_P									
8	not in use												
9	not in use												
10	P	W	BD	H_S									
11	P	C_0	W_d	W_i	H_p								
12	P	ET_{mx}	a	b	H_S								

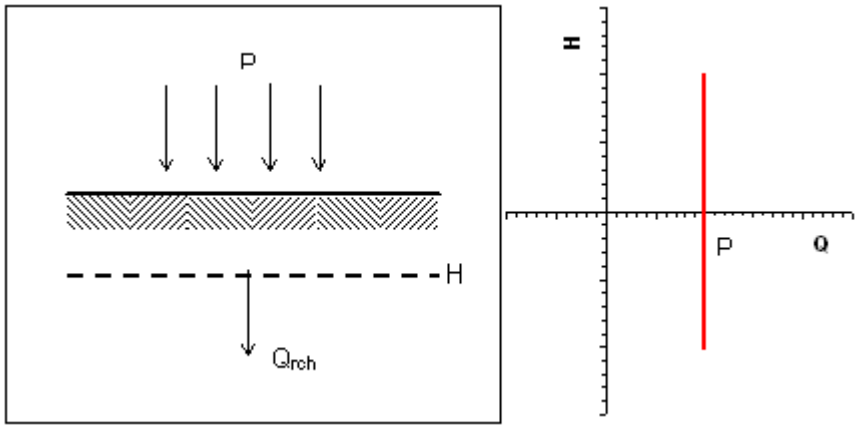
Name	Definition of parameter
P	Precipitation excess or irrigation excess
ET_{mx}	Maximum Evapotranspiration
A	soil parameter obtained by curve fitting
B	soil parameter obtained by curve fitting (b > 1)
C_0	Hydraulic resistance of semi-pervious top layer
H_d	Drain level of system of (pipe)—drains
H_P	Polder water level or controlled water level
H_S	Surface level (with respect to the ordnance level)
H_T	Level of base of semi-pervious top layer
K_h	Horizontal permeability of semi-pervious top layer
K_v	Vertical permeability of semi-pervious top layer
L	Horizontal distance between drains
R	Wetted perimeter of (pipe)—drains
BD	Drainage base or bottom level of the (open) drains
BD_1	Drainage base or bottom level of the primary drainage system
BD_2	Drainage base or bottom level of the secondary drainage system
BD_3	Drainage base or bottom level of the tertiary drainage system
W	Drainage or infiltration resistance between ditches or drains
W_d	Drainage resistance between ditches or drains
$W_{d,1}$	Drainage resistance of the primary drainage system
$W_{d,2}$	Drainage resistance of the secondary drainage system
$W_{d,3}$	Drainage resistance of the tertiary drainage system
W_I	Infiltration resistance between ditches or drains
$W_{i,1}$	Infiltration resistance of the primary drainage system
$W_{i,2}$	Infiltration resistance of the secondary drainage system
$W_{i,3}$	Infiltration resistance of the tertiary drainage system

A.3 Topsystem 1: Precipitation or irrigation without drainage

Code number: IR = 1

Description: Groundwater recharge or discharge is specified, equal to the precipitation or irrigation excess. The flux is independent of the piezometric head in the top aquifer.

Equation:



General parameters:

	Q_{rch}	groundwater recharge

User defined parameters:

RP1	P	precipitation or irrigation excess

Applications:

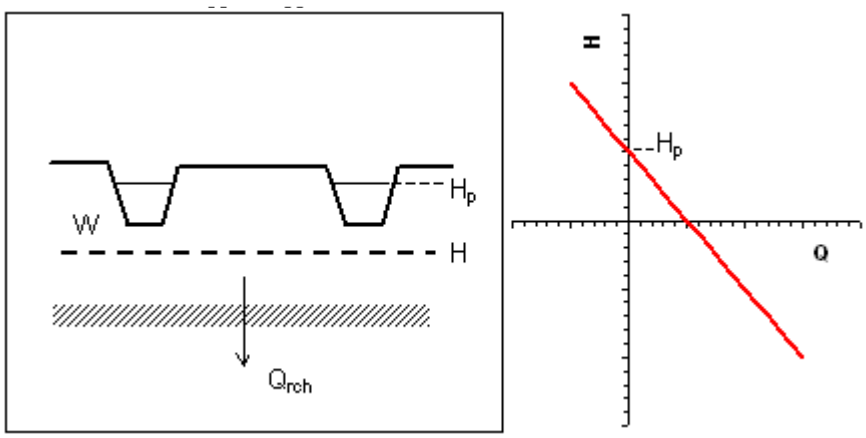
- Groundwater recharge or discharge is known.
- Groundwater recharge is used as calibration parameter, rather than recharge relation.

A.4 Topsystem 2: Polder with fixed water level

Code number: IR = 2

Description: Groundwater recharge and discharge depend on the controlled water level of the polder, the drainage resistance of the system, the vertical hydraulic resistance of the semi-pervious top layer and the piezometric head in the top aquifer.

Equation:



General parameters:

	Q_{rch}	groundwater recharge
	H_1	groundwater head of the first aquifer

User defined parameters:

RP1	H_p	polder water level
RP2	C_0	hydraulic resistance of semi-pervious top layer
RP3	W	drainage or infiltration resistance

Applications:

- Simulation of a polder with a constant (fixed) polder water level.
- Simulation of (large) surface water bodies (with negligible drainage resistance).
- Simulation of areas where known piezometric heads must be generated (by neglecting the drainage resistance and the hydraulic resistance of the semi-pervious top layer).

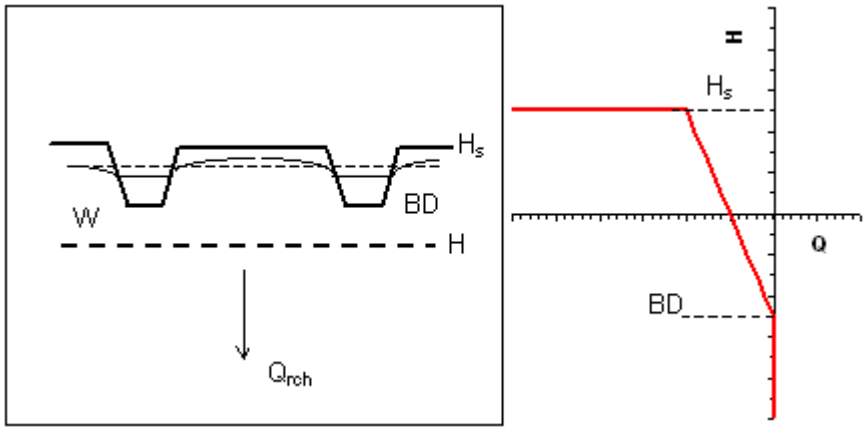
Note:

- This top-system does not account for any precipitation.
- The hydraulic resistance of the semi-pervious top layer will cause the program to compute a difference in head between the aquifer and the semi-pervious top layer.

A.5 Topsystem 3: Phreatic drainage

Code number: IR = 3

Description: Groundwater discharge depends on the piezometric head in the top aquifer, the base-elevation of the drainage system (e.g., the bottom-level of the drainage system), the drainage resistance and the topographic level (the elevation of the ground surface).



Equation:
Three sets of equations are used, depending on the value of the phreatic piezometric head (H_1).

1. $BD \geq H_1$ $\quad Q_{rch} = 0$
2. $BD \leq H_1 \leq H_s$ $\quad Q_{rch} = \frac{BD - H_1}{W}$
3. $H_1 > H_s$ $\quad Q_{rch} = Q_{dr} + Q_{ro}$

with: $Q_{dr} = \frac{BD - H_s}{W}$ and $Q_{ro} = \frac{H_s - H_1}{W_{ro}}$

General parameters:

	Q_{rch}	groundwater recharge
	Q_{dr}	groundwater flux to the drains
	Q_{ro}	surface run-off
	H_1	groundwater head of the first aquifer
	W_{ro}	hydraulic resistance for surface run-off $W_{ro} = 0.1 * W$

User defined parameters:

RP1	H_s	topographic or surface level
RP2	W	drainage resistance
RP3	BD	base elevation of drainage system

Applications:

- Simulation of seepage areas with drainage by drains trenches or furrows.

Note:

- This top-system does not account for any precipitation.
- Due to the absence of a semi-pervious top layer the program computes no difference between the phreatic head and the head in the first aquifer: (PHIT = PHI1).

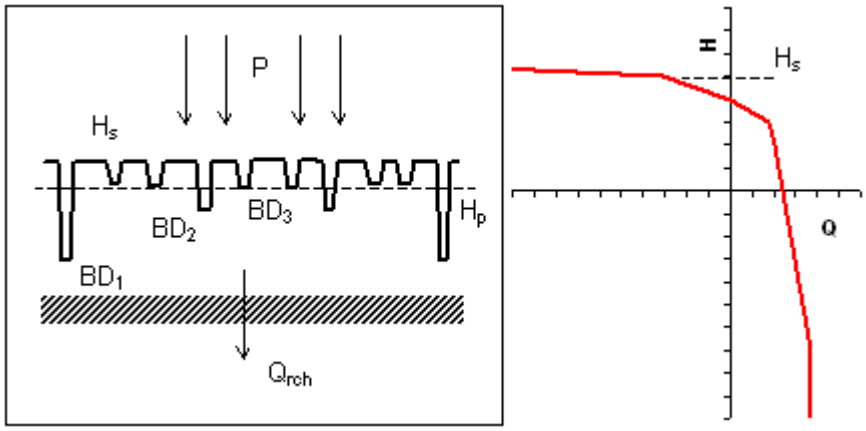
A.6 Topsystem 4: Three-level drainage/infiltration system

Code number: IR = 4

Description: Drainage and infiltration are defined by three separate drainage systems. Each system is described by three parameters.

- a drainage resistance,
- an infiltration resistance and
- a minimum elevation, the bottom level of the system considered.

Whether or not a system is active depends on the value of the controlled water level, which is the same for all three systems. If the controlled level rises above the bottom of the system, the system is active. Infiltration will take place if the controlled level is higher than the head in the top-system. Drainage will take place if the controlled level is lower than the head in the top-system.



Equation:
The basic equation is the water balance of the top-system.

$$P = Q_{rch} + Q_{dr,1} + Q_{dr,2} + Q_{dr,3} + Q_{ro}$$

The flux to the various drainage systems ($Q_{dr,j}$), the surface run-off component (Q_{ro}) and the recharge (Q_{rch}) all depend on the phreatic groundwater head in the top layer.

These fluxes are calculated according to the following equations:

$$Q_{rch} = \frac{H^* - H}{C_0}$$

$$Q_{dr,j} = \frac{H^* - L_j}{W_j} \qquad \text{for } H^* > BD_j \quad \text{and } j = 1, 2, 3$$

$$Q_{ro} = \frac{H^* - H_s}{W_{ro}}$$

Here is:

$$L_j = \max\left(H_p ; BD_j\right) \qquad \text{in case of drainage by system } j$$

$$L_j = H_p \qquad \text{in case of infiltration by system } j$$

and:

$W_j = W_{i,j}$ for $H^* \leq L_j$ i.e., in case of infiltration

$W_j = W_{d,j}$ for $H^* > L_j$ i.e., in case of drainage

Drainage will be computed for the three systems separately but only if for that system $H^* \geq BD_j$ and $H^* \geq H_p$. Similarly, also infiltration will be computed for the three systems separately. However, it only will take place if, for the system concerned, $H^* \leq BD_j$ and $H_p \geq BD_j$.

Surface run-off Q_{ro} will only be computed if $H^* \geq H_s$. Infiltration through the surface level never will be allowed, not even if $H_p \geq H_s$. In that case the surface water is supposed to be separated from its surroundings by dikes.

General parameters:

	Q_{rch}	groundwater recharge
	$Q_{dr,1}$	flux to and from the drains of the primary system
	$Q_{dr,2}$	flux to and from the drains of the secondary system
	$Q_{dr,3}$	flux to and from the drains of the tertiary system
	H_1	groundwater head of the first aquifer
	H^*	average groundwater head of the top-system
	W_{ro}	hydraulic resistance for surface run-off $W_{ro} = 1.0$ day

User defined parameters:

RP1	P	precipitation excess
RP2	C_0	hydraulic resistance of semi-pervious top layer
RP3	H_p	controlled or polder water level
RP4	$W_{d,1}$	drainage resistance of primary drainage system
RP5	$W_{d,2}$	drainage resistance of secondary drainage system
RP6	$W_{d,3}$	drainage resistance of tertiary drainage system
RP7	$W_{i,1}$	infiltration resistance of primary drainage system
RP8	$W_{i,2}$	infiltration resistance of secondary drainage system
RP9	$W_{i,3}$	infiltration resistance of tertiary drainage system
RP10	BD_1	base elevation of primary drainage system
RP11	BD_2	base elevation of secondary drainage system
RP12	BD_3	base elevation of tertiary drainage system
RP13	H_s	topographic or surface level

Applications:

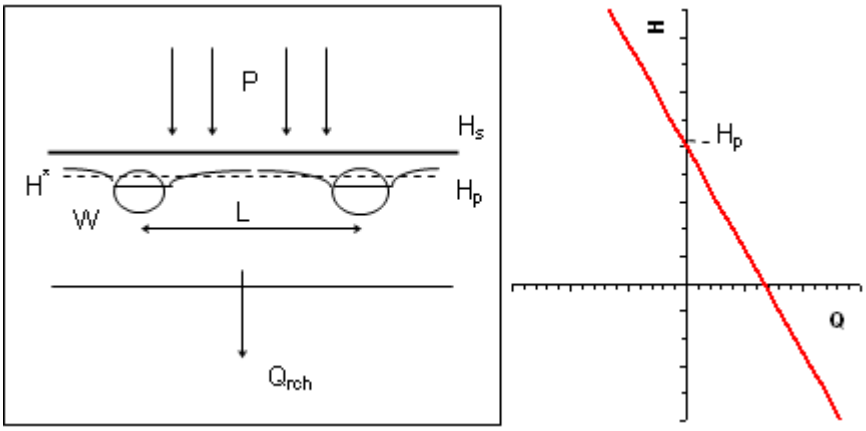
- Simulation of areas with drainage or infiltration by a drainage system that may be regarded as a combination of three separate systems: a primary, secondary and tertiary drainage system. For instance main watercourses, ditches and trenches or furrows. Each system has its own drainage characteristics.

A.7 Topsystem 5 and 6: Pipe drainage and irrigation or precipitation

Code number: IR = 5 and IR = 6

Description: Groundwater recharge and discharge depend on the precipitation or irrigation excess, the piezometric head in the top aquifer and the drainage resistance. The drainage resistance depends on the distance between the drains, the horizontal and vertical permeability of the semi-pervious top layer, its thickness and of the wetted perimeter of the drains.

Two versions of this top-system are available:
- The system with code number **5** only allows the drains to discharge groundwater (drainage).
- The system with code number **6** allows both discharge and recharge of groundwater by the drains (drainage and infiltration).



Equation:
The basic equation is the water balance of the top-system.

$$P = Q_{rch} + Q_{dr}$$

Depending on the geometry and the permeabilities of the top layer one of the following sets of equations is applied. The criterion for choosing which set to use, is whether or not the thickness of that part of the top layer that is below the drainage level is larger than a given coefficient. This coefficient is by definition:

$$\frac{\sqrt{K_v}}{\sqrt{K_h}} * \frac{L}{\pi}$$

Situation 1: if $D \geq \frac{\sqrt{K_v}}{\sqrt{K_h}} * \frac{L}{\pi}$ the next set of equations is used.

$$Q_{dr} = \frac{-(H_1 \cdot \pi \cdot K_v + P \cdot \pi \cdot D)}{A}$$

and

$$Q_{rch} = \frac{H_1 \cdot \pi \cdot K_v - PL\frac{\sqrt{K_v}}{\sqrt{K_h}} * \ln\left(\frac{2\sqrt{K_v}}{\sqrt{K_v}+\sqrt{K_h}} * \frac{L}{2R}\right)}{A}$$

with:

$$A = \frac{\pi D}{L} + \frac{\sqrt{K_v}}{\sqrt{K_h}} * \ln\left(\frac{2\sqrt{K_v}}{\sqrt{K_v}+\sqrt{K_h}} * \frac{L}{2R}\right)$$

Furthermore, the phreatic head in the top layer and the (radial) hydraulic resistance of the drains can be expressed as:

$$H^* = \left(H_1 + \frac{P\,D}{K_v}\right) * \frac{\ln\left(\frac{2\sqrt{K_v}}{\sqrt{K_v}+\sqrt{K_h}} * \frac{L}{2\,R}\right)}{A}$$

and

$$W_r = \frac{H_1\,L}{Q_{dr}} = \frac{D}{K_v} + \frac{L}{\pi\sqrt{K_h\,K_v}} * \ln\left(\frac{2\sqrt{K_v}}{\sqrt{K_v}+\sqrt{K_h}} * \frac{L}{2\,R}\right)$$

Situation 2: if $D < \frac{\sqrt{K_v}}{\sqrt{K_h}} * \frac{L}{\pi}$ the next set of equations is used.

$$Q_{dr} = \frac{-\left(H_1 * \pi * K_v + P * \pi * D\right)}{\frac{\sqrt{K_v}}{\sqrt{K_h}} * \ln\left(4.27\frac{2\sqrt{K_v}}{\sqrt{K_v}+\sqrt{K_h}} * \frac{D}{R}\right)}$$

and

$$Q_{rch} = -\,Q_{dr} - P \cdot L$$

The phreatic head in the top layer and the (radial) hydraulic resistance of the drains now can be expressed as:

$$H^* = H_1 + \frac{P \cdot \left(D + H^*\right)}{K_v}$$

and

$$W_r = \frac{H_1\,L}{Q_{dr}} = \frac{L}{\pi\sqrt{K_h\,K_v}} * \ln\left(4.27\,\frac{2\sqrt{K_v}}{\sqrt{K_v}+\sqrt{K_h}} * \frac{D}{R}\right)$$

General parameters:

	Q_{rch}	groundwater recharge
	Q_{dr}	flux to and from the drains
	H^*	phreatic head of the top-system
	H_1	groundwater head of the first aquifer
	D	the thickness of the top-system below drainage level: $D = H_d - H_T$
	W	the (radial) resistance to flow towards the drain

User defined parameters:

RP1	P	precipitation or irrigation excess
RP2	H_s	topographic or surface level
RP3	H_d	drain level of system of (pipe)-drains
RP4	H_T	level of the base of the semi-pervious top layer
RP5	K_v	vertical permeability of the semi-pervious top layer
RP6	K_h	horizontal permeability of the semi-pervious top layer
RP7	L	horizontal distance between the drains
RP8	R	the wetted perimeter of the drain

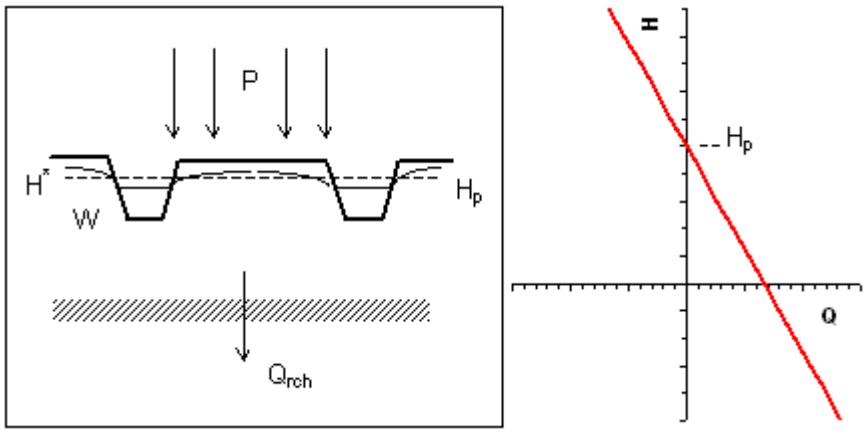
Applications:

- Simulation of areas where precipitation or irrigation partly recharges the top aquifer and is partly discharged by a drainage system. Moreover this top-system facilitates calculation of a drainage resistance if the layout of the drainage system and the soil characteristics are known.

A.8 Topsystem 7: Polder with a fixed water level and precipitation

Code number: IR = 7

Description: Groundwater recharge and discharge depend on a controlled polder water level, the drainage resistance, the vertical hydraulic resistance of the semi-pervious top layer, the precipitation excess and the piezometric head in the top aquifer. The water level between the drains is higher than the controlled level in the drains due to the precipitation excess.



Equation:
The basic equation is the water balance of the top-system.

$$P = Q_{rch} + Q_{dr}$$

Here is:

$$Q_{rch} = \frac{H^* - H_1}{C_0}$$

And

$$Q_{dr} = \frac{H^* - H_p}{W}$$

General parameters:

	Q_{rch}	groundwater recharge
	Q_{dr}	flux to and from the drains or ditches
	H^*	phreatic head of the top-system
	H_1	groundwater head of the first aquifer

User defined parameters:

RP1	P	precipitation or irrigation excess
RP2	C_0	hydraulic resistance of semi-pervious top layer
RP3	W	drainage resistance of drainage system
RP4	H_p	controlled or polder water level

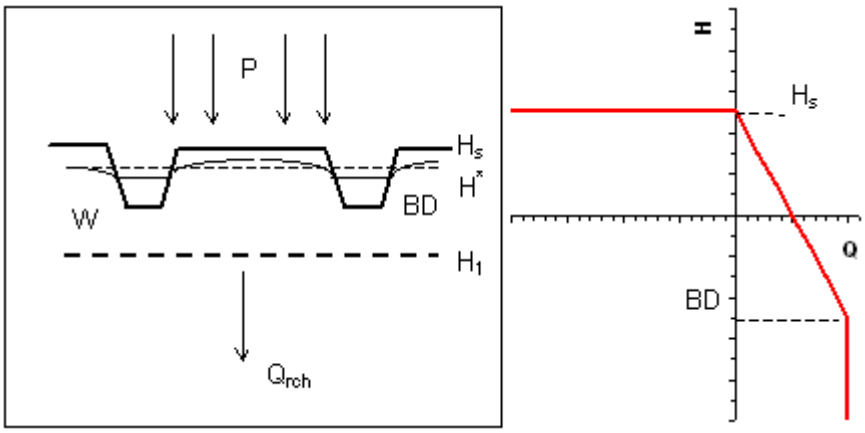
Applications:

- Simulation of a polder-system with a constant water level, where the difference between the average level of the ground water table and the water level in the ditches can not be neglected.

A.9 Topsystem 10: Phreatic drainage with precipitation

Code number: IR = 10

Description: Groundwater discharge depends on the (phreatic) piezometric head in the top aquifer, the base elevation of the drainage system, the drainage resistance, the topographic or surface level and the precipitation or irrigation excess. This top-system accounts for a difference between the average level of the water table and the surface water, due to precipitation.



Equation:
Three sets of equations are used, depending on the value of the phreatic piezometric head.

1. $BD \geq H^*$ $\quad Q_{rch} = P$
2. $BD \leq H^* \leq H_s$ $\quad Q_{rch} = P - \frac{(BD - H^*)}{W}$
3. $H^* > H_s$ $\quad Q_{rch} = P - Q_{dr} - Q_{ro}$

With: $Q_{dr} = \frac{BD - H_s}{W}$ and $Q_{ro} = \frac{H_s - H^*}{W_{ro}}$

General parameters:

	Q_{rch}	groundwater recharge
	Q_{dr}	groundwater flux to the drains
	Q_{ro}	surface run-off
	H^*	phreatic head of the top-system
	W_{ro}	hydraulic resistance for surface run-off ($W_{ro} = 0.1 * W$)

User defined parameters:

RP1	P	precipitation or irrigation excess
RP2	W	drainage resistance of the system
RP3	BD	base elevation of drainage system
RP4	H_s	topographic or surface level

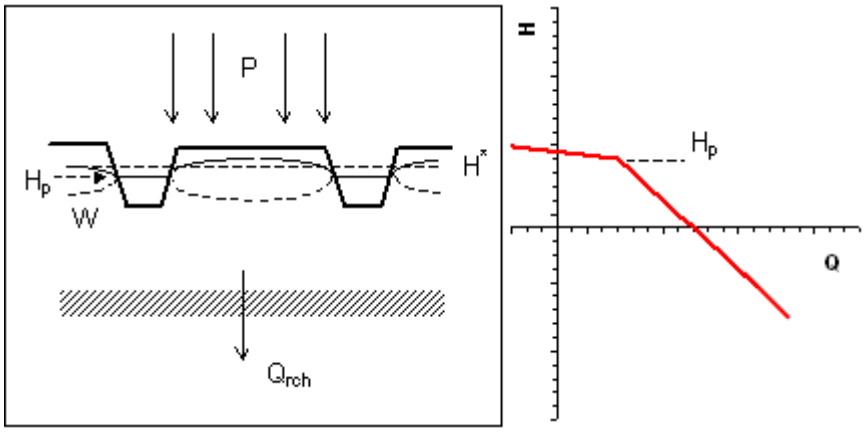
Applications:

- Simulation of groundwater discharge in areas with a phreatic groundwater surface and with drains and furrows. Both infiltration and seepage may occur. Infiltration, however, may not exceed the amount of precipitation or drainage.

A.10 Topsystem 11: Polder with a fixed water level and single drainage system

Code number: IR = 11

Description: Groundwater recharge and discharge depend on a controlled surface-water level, the vertical hydraulic resistance of the semi-pervious top layer, the precipitation excess and the piezometric head in the top aquifer. Moreover, groundwater recharge depends on an infiltration resistance, whereas groundwater discharge depends on a drainage resistance. This top-system accounts for the difference between the average value of the water table and the water level in the canals or drains.



Equation:
The basic equation is the water balance of the top-system.

$$P = Q_{rch} + Q_{dr}$$

Here is:

$$Q_{rch} = \frac{H^* - H_1}{C_0}$$

and the groundwater flux towards the drainage system depends on the phreatic head, relative to the controlled (surface) water level:

$$\text{if } H^* \le H_p \quad Q_{dr} = \frac{H_p - H^*}{W_i}$$

$$\text{if } H^* > H_p \quad Q_{dr} = \frac{H_p - H^*}{W_d}$$

General parameters:

	Q_{rch}	groundwater recharge
	Q_{dr}	groundwater flux to the drains
	Q_{ro}	surface run-off
	H^*	phreatic head of the top-system

User defined parameters:

RP1	P	precipitation or irrigation excess
RP2	C_0	hydraulic resistance of semi-pervious top layer
RP3	W_d	drainage resistance of the drainage system
RP4	W_i	infiltration resistance of the drainage system
RP5	H_p	controlled or polder water level

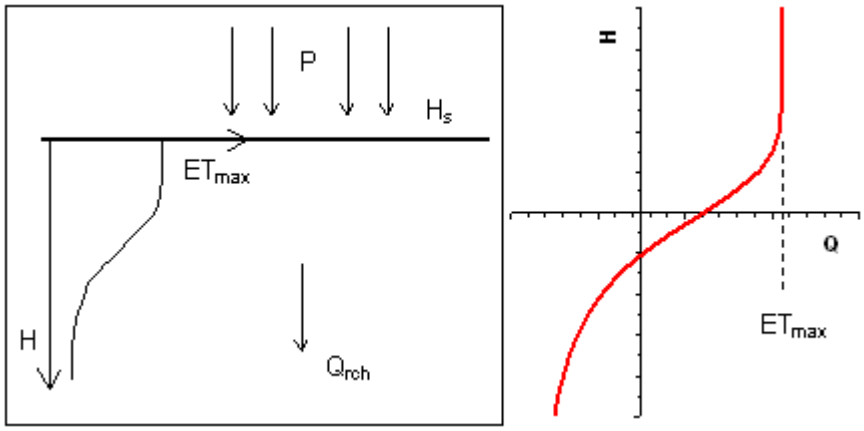
Applications:

- Simulation of an area with infiltration and drainage systems. Generally the drainage system differs from the infiltration system. Example: For the main canals a constant water level is prescribed (infiltration situation), while the secondary canals may start draining water, or even stop discharging water.

A.11 Topsystem 12: Predefined recharge or discharge characteristic

Code number: IR = 12

Description: Groundwater recharge or discharge depends on the calculated phreatic head. Two parameters are used. The values of these parameters need to be established by curve fitting of the recharge/discharge characteristic of the soil. The solution can be considered as a steady-state approximation of the Van Genuchten relations.



Equation:
The equation used depends on the phreatic piezometric head in the first aquifer and on the soil parameters:

$$\text{if} \quad H_1 \le H_s \quad Q_{rch} = P + \frac{ET_{mx} - P}{\left(1 + \alpha \left(H_s - H_1\right)^{\beta}\right)^{\frac{\beta-1}{\beta}}}$$

$$\text{if} \quad H_1 > H_s \quad Q_{rch} = ET_{mx}$$

General parameters:

	Q_{rch}	groundwater recharge due to precipitation and evaporation near the surface
	H_1	average groundwater head of the first aquifer

User defined parameters:

RP1	P	precipitation or irrigation excess
RP2	ET_{mx}	the maximum evapotranspiration (positive in downward direction)
RP3	α	parameter depending on soil characteristics
RP4	β	parameter depending on soil characteristics ($b > 1$)
RP5	H_s	topographic or surface level

Applications:

- Fast approximation of unsaturated distributions to the saturated layer.